VOLUME V NUMBER 3

BULLETIN

OF THE

AMERICAN ASSOCIATION

OF

PETROLEUM GEOLOGISTS

MAY—JUNE, 1921

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

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THE BULLETIN is the official publication of the Association, and it is to be published in six numbers with a subscription price of $5.00 per year. Extra postage on annual subscriptions is 30 cents for Canada and 53 cents for all other foreign countries to which postage is more than the local amount. Communications for the Editor and manuscripts should be addressed to R. C. Moore, Lawrence, Kansas. Remittances and business correspondence should be sent to C. E. Decker, Norman, Okla. Correspondence regarding advertisements should be addressed to E. DeGolyer, 65 Broadway, New York City.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

Vol. I (bound)	$2.50	Vol. IV, Nos. 1, 2, or 3, each	$2.00
Vol. II (bound)	2.50	Vol. V, Subscription, 1921	5.00
Vol. III (bound)	4.00	Vol. V, Nos. 1, 3, each	1.00
Vol. IV, 1, 2, 3	5.00	Vol. V, No. 2 (double size)	2.00

Published by the American Association of Petroleum Geologists bi-monthly, at Lawrence, Kansas. Entered as second class matter April 15, 1921 at the postoffice at Lawrence, Kansas under the Act of March 3, 1879.

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THE OUTLOOK FOR OIL AND GAS IN PENNSYLVANIA

By George H. Ashley*

INTRODUCTION

One of the largest questions before the public today is the source of future supplies of oil and gas. Pennsylvania has passed from the position of the leading producer of both oil and gas to a secondary place in the production of gas and to the position of tenth among the states in the production of oil. The oil and gas wells of Pennsylvania, however, have a staying power that may keep the state in the game for many years to come and while the actual production may steadily decline, the relative position of Pennsylvania may improve through the more rapid decline of the oil and gas fields of other states.

OUTLOOK FOR OIL

The outlook for oil is different from that for gas so the two may be considered separately. The large scale production of oil began in Vanango county, Pennsylvania, in 1859. From the point of "discovery" at Titusville drilling spread slowly over the adjoining counties. At first, it was confined to the stream valleys. Then it was discovered that oil could be gotten under the hills though at greater depths. Gradually drilling spread northeastward to the Bradford field and southward

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to the Butler and Clarion fields. Then oil was found in Washington county, resulting in bringing the state's production up to about 30 million barrels a year in the early '90's. Since that time nearly every part of the state has been tested so that it appears probable that a fairly accurate estimate may be made today of the outlook if not of the actual future production.

Eastern limit of oil fields.—It appears probable that the actual productive oil area of the state has already been closely outlined. As shown on a map, the oil and gas fields of Pennsylvania are, in the main, limited to a belt 30 to 60 miles wide lying from northeast to southwest across the west end of the state. This belt lies on either side of a line from the northeast corner of McKean county past Clarion and Pittsburgh to the southwest corner of the state. Nearly all of the oil lies west of this central line while the gas lies on either side but mainly to the east. Southeast and northwest of this main belt are scattered gas fields, extending on the southeast nearly to the southeastern edge of the bituminous coal field. The oil fields of the state are limited on the east by a fairly sharp line which in a general way runs from the northeast corner of McKean county, just east of Clarion and Pittsburgh, to a point a little east of the southwest corner of the state. A few pools lie east of this line as, for example, the Gaines and Fayette pools and several pools in the south and southeast parts of Green county. Aside from these pools only minor showings of oil have been found east of this line notwithstanding that thousands of wells have been drilled which found a large amount of gas, it appears probable that the part of the state east of the line may be definitely considered as out of the main oil area of the state.

Northwest limit of oil fields.—The exact boundary of the oil fields on the northwest is less definite than on the east. The lack of oil in Mercer, Crawford and Erie counties is due primarily to the disappearance in that direction of most of the oil bearing sands. In general, all of the sands, except the Berea, and Salamanca or Third sand have thinned out under most of these counties. The Berea is thin, 8 to 30 feet, and the Salamanca very thin, 2 to 15 feet, where they outcrop

across Erie and Crawford counties. Since, however, the Berea is thick in northeastern Ohio and in Venango county, it would seem probable that it is thick in places in Mercer, Crawford and southern Erie counties. It is also possible, if not probable, that if such areas of thick Berea exist, some of them will contain oil. Exposures of the Salamanca sandstone or Third oil sand are everywhere charged with petroleum. These sandstones probably may be counted on for some oil and possibly for a considerable production. The finding of oil in these northwestern counties will be difficult because the structure is a gentle monocline and the hard rocks are buried beneath a mantle of glacial debris. It will, therefore, be merely a matter of indiscriminate testing.

A further probable source of oil in the northwestern counties of the state exists in the deep Medina sandstone ("Clinton sand" of Ohio) which is gas-bearing all along the south shore of Lake Erie and down through central Ohio but which has yielded some oil in east-central Ohio, and is possibly the source of a little oil which has come from wells in Erie county. This sand occurs at a depth of about 2,500 feet below the surface at Erie or about 1,800 feet below sea level. At Pittsburgh this sand is about 7,300 feet below sea level.

FUTURE OIL FROM MAIN FIELD

Production from Present Wells.—Coming now to the main field there are four angles to the problem of the future supply of oil in Pennsylvania. First, there is the anticipated future production of present wells. There were in 1918 about 58,850 productive wells in Pennsylvania having an average production of about 1-3 of a barrel a day. The new wells drilled that year had an average initial daily production of 2.9 barrels. The total production for the year was made up from wells of all ages including those just drilled and those ready to be abandoned some of which were 30 years or more old. If it be assumed that all new drilling were stopped, the total future production could hardly exceed a total of a little over 50 million barrels. The total would probably be much under that. This decline for the first year would be about 7 million barrels and production would continue for about 30 years.

Production from New Drilling.—In the second place, what may be expected from the new drilling?

(1) The percentage of dry holes has perceptibly decreased as the amount of wild catting has decreased. This is shown by the following figures:

Record of Wells Drilled in Pennsylvania for Selected Years, 1890 to 1920

	1890*a*	1895*a*	1900*b*	1905	1910*b*	1915	1918	1920*c*
New Wells	6358	6676	4451	3095	2201	1808	1827	3113
Dry	1049	1463	974	763	285	280	212	306
Percent dry wells	16	20	21	24	13	16	11	09

a includes northern West Virginia; *b* includes Allegheny county, New York; *c* does not include McKeesport.

(2) The average initial production has shown a fairly steady decline from the early days of the McDonald field in the early '90's. The following table shows what has been happening in this regard:

Average Initial Production of Wells in Pennsylvania by Fields for Selected Years

Field	1891	1895	1899	1905	1910	1915	1918	1920	Jan. 1921
Bradford	6.1	6.8	7.5	3.7	3.0	3.3	2.7	2.6	2.2
Middle	8.4	7.8	4.9	2.8	2.2	2.2	2.3	1.4	1.2
Venango-Clarion	6.9	4.3	3.0	2.5	2.0	1.4	1.9	1.5	1.3
Butler-Armstrong	37.9	19.3	7.8	10.2	9.8	19.1	2.6	4.0	2.2
Southwest	148.3	38.4	34.0	9.6	13.8	16.2	7.6	12.2	3.7

The figures for southwestern Pennsylvania in 1920 are higher by 12 per cent than they would otherwise have been because of one large well in Green county. While these figures show that the decline is irregular, the general fact of the decline is too obvious to be mistaken. From the figures quoted, it is evident that most of the drilling of recent years has been in proven territory and probably at points from which some of the oil had previously been withdrawn by earlier drilling. Decline curves are not yet available to show how wells drilled in recent years compare with older wells in staying powers. It is anticipated, however, that, as most of the recent drilling has been in the gaps left in earlier drilling, the wells will be shorter lived. The combination of reduced initial flow and possible shorter life will, in time, act together to bring the

total flow of the average well to a point where it will not pay the cost of drilling and maintenance. An increase in the price of crude petroleum will postpone the coming of such a time, assuming that the cost of drilling does not increase correspondingly. In some of the fields it would appear that the point of vanishing profits would be reached in about 10 or 15 years unless new sands are found or some means devised for renewing the wells.

For over 10 years production of oil has been maintained at between 7 and 8 million barrels or a little over. A comparison of the total number of new wells with the total production for the years 1900 to 1920, inclusive, gives definite evidence of a decline.

New Wells and Production in Pennsylvania, 1900-1920 Inclusive

Year	New initial production in barrels	No. of new wells	Aver. initial production in barrels	Total production in barrels	Average price per barrel
1900	32,528*a*	3477*a*	9.3	13,741,801	$1.35
1902	19,656*a*	2875*a*	6.9	12,414,857	1.23
1904	13,835	2614	5.2	11,125,762	1.62
1906	14,875	3104	4.7	10,256,893	1.59
1908	9,098	2996	3.0	9,424,325	1.78
1910	6,315	1918	3.2	8,794,662	1.33
1912	6,493	2226	2.9	7,837,948	1.64
1914	6,627	2032	3.2	8,170,335	1.88
1916	10,774	2298	4.6	7,592,394	2.51
1918	4,621	1423	3.2	7,407,812	3.25
1920	8,641	2600	3.3	7,454,400	6.10
1920*b*	7,241	2599	2.8		
1921*c*	409	184	2.22		

a includes New York and West Virginia; *b* without Meeks well; *c* January only.

A study of this table in connection with production curves brings out the following facts regarding the production of oil in Pennsylvania: (1) a fairly steady rise of production to 1874 with a slight decline to 1876; (2) the opening of the Bradford field in which production increased rapidly to a maximum of 25,000,000 barrels with a corresponding decline in the other fields of the state; (3) in 1885 and 1886 the production from Washington and Green counties became prominent, increasing the total production of the state by 5,500,000 barrels in 1886, followed by the usual decline; (4) in 1890

and 1891 the McDonald field came in with a number of very large wells which with a general growth in the southwestern district doubled the output of the state between 1888 and 1891; and (5) from 1891 there has been a nearly steady decline, very rapid at first (from 1891 to 1912), since when the production has been irregular but definitely indicative of a continuing decline. If the rate of decline from 1914 to 1920 continued uniformly, the production of Pennsylvania would reach its end about 1980 with a total additional production of about 220,000,000 barrels of oil.

The decline will be affected by three factors. First, the decline curve tends to flatten which may prolong the production of oil for many years. Second, the point of vanishing profits will be reached long before the normal production reaches zero, as previously explained. Third, there is the latent possibility of finding new pools or of reviving old pools so as to lift the curve to a new level. This brings us to the third angle of the problem, the possibility of finding new pools.

New Oil Pools.—As already pointed out, the thousands of wells drilled east of the main oil field which, while finding gas, have failed to find oil, seem to indicate the absence of any large pools of oil in this direction. That additional small pools will be found is to be anticipated. The chance of finding small pools northwest of the main field is much better and there is a possibility that other pools as large as the Volant will be revealed, with the bare possibility that deep drilling may open up a large reservoir of oil in the Medina sand in west central Pennsylvania.

Within the main field, however, the outlook is for a continuation of the present method of testing the gaps left in earlier drilling with the prospects of an occasional good well (that is, 100 to 1,000 barrels initial daily production) but with a general tendency toward a steady decline in initial production to a minimum where the return of the average well does not pay the drilling, interest and amortization costs. Large parts of the main oil fields have had a drill hole sunk in every square mile and hold out no hope of new pools. Other parts have been tested less thoroughly and may prove to contain many new pools, some of which may be of real importance

though there does not seem to be any possibility of finding any large pools, such as the Bradford or McDonald, which would produce a large upward jump in the state's production.

The question is often asked, are there not lower sands as yet untouched in the oil fields which may renew or increase their life? Continued study of the problem seems to lead to two conclusions, first, that during recent years many scattered holes have been drilled to depths of from 4,000 to 7,000 feet or more which seemed to have tested the sands to that depth in nearly all parts of the field and, second, that these holes have, as a rule, found in the deeper sands only gas or nothing.

It, therefore, apears that while much new oil and many new pools are certain to be found, the prospects are not bright for the finding of any new large deposits of oil in the state.

Rejuvenation of Old Fields.—There remains one important phase of the problem. It is recognized that from a hard, small-pored sandstone such as certain of the oil sands of Pennsylvania are believed to be, the initial production of oil wells is, on the average, small, and the decline, so long drawn out, is due in part to the sealing of wells in the sand by paraffin and in part to the reduction in pressure needed to force the oil into a well. Will it be possible to revive pools or fields near exhaustion by the removal of the paraffin or the introduction of new pressure? How much additional oil may be obtained from revived wells?

The removal of the paraffin, by methods which need not be reviewed here, is claimed to have increased the flow of oil from a given property by 300 per cent. As the methods and results of the rejuvenation of the Bradford field have been published recently in Bulletin 148, issued by the U. S. Bureau of Mines, it is not necessary here to go into details. The rejuvenation of the Bradford field has not been in operation long enough to show exactly what the final returns per acre will be. From such data as are on hand, Lewis, in the report mentioned, estimates that the use of the Smith-Dunn (compressed air) or other processes may not be counted upon to increase the production of the average pool in the Appalachian field more than 50 per cent and that such an increase will

be possible only when the operation is maintained as long as it can be made to pay. If it be assumed that the total production of oil in Pennsylvania to 1921 has been over 750,000,000 barrels and that the future production without the use of special methods of recovery will bring the total to 900,000,000 barrels, it may be estimated that the use of special methods of recovery may increase this by one-half or to 1,350,000,000 barrels. That estimate postulates a total future recovery of 600,000,000 barrels.

At present this may appear like a purely theoretic recovery but it is based on the results of actual experience. It may be more conservative to assume a total recovery of 1,000,000,000 barrels of which nearly 250,000,000 barrels, or one fourth, are still to be gotten. But the possibility of a much greater recovery should not be lost sight of, particularly in view of the prospect of ever increasing prices for crude petroleum and of the certainty that future inventions will revolutionize our methods of recovery.

It may, therefore, be anticipated that notwithstanding new drilling the production of oil in Pennsylvania is destined to decline slowly and steadily to a vanishing point which may not be reached for 100 years but which may be approached within 20 or 30 years.

THE OUTLOOK FOR GAS

The outlook for gas differs materially from that for oil, especially in three respects: (1) exhausted gas pools are exhausted for all time; (2) the gas fields cover a much wider territory much of which has not been fully tested and part of which has hardly been tested at all; and (3) the deeper sands, which hold out little promise of oil, may hold in reserve large volumes of gas.

Exhausted Gas Pools.—A body of gas in a porous sandstone differs from a similar body of oil in that it appears to flow more readily so that under the action of high vacuum pumps it would appear that all of the gas in a pool is drawn out. This does not mean that there may not be detached pools in the midst of or adjoining the main pool which are shut off from the main pool by non-porous sand. The McKeesport gas pool was entirely cut off from adjoining pools on the north.

The future supply of gas in Pennsylvania must, therefore, depend on (1) the life of the present gas wells, (2) the drilling of new wells in the fields not yet exhausted, and (3) the finding of new pools or new fields.

Life of Present Wells.—A gas well has a life much like that of an oil well though with some slight differences. Because of the readier flow of gas through the rock, it is sometimes true that a gas well will continue to yield the same flow for a long time or may even increase its flow for a time as the current of gas under its high pressure may dislodge the grains of sand in the sandstone and open up channels to the well. Thus, some of the earlier wells at McKeesport blew sand into the pipe for months after they were opened.

Again, it is possible, by the use of high vacuum pumps, to continue the life of a gas well for a very long period after the pressure has been reduced to atmospheric pressure. This feature also is well illustrated by the McKeesport pool. It is a surprise to most persons, after the rapid decline of the McKeesport pool in the spring of 1920, to learn that the pool entered 1921 making about 9,000,000 cubic feet of gas a day with the prospect of running many months into the year. It must be remembered, however, that this production has been maintained only by steadily lowering the pressure with pumps or, as it is more commonly expressed, increasing the vacuum.

In the past, gas wells like oil wells have differed in length of life from a few months to 30 years or more. Wells recently drilled in new fields are as likely to have long life as wells drilled 30 years ago, provided, that drilling today or in the future is not more closely spaced than in the past. This means that some wells which are drilling today will be flowing 30 years from now. In general, however, it may be anticipated that new fields will be more and more closely drilled with the result of reducing the life of the wells now flowing,

If no more wells were drilled, it might be closely estimated that the production of natural gas in Pennsylvania will decline rapidly at first, then more and more slowly to extinction in 30 or 40 years. In 1918 the gas production of the state was nearly 124,000,000,000 cubic feet. If not replenished by new drilling it is probable that 5 years would see that amount

reduced one half, ten years to one quarter, and so on, yielding a total future production of less than 1,000,000,000,000 cubic feet.

Prospects from New Drilling in Old Pools.—New drilling may be of two kinds. First, the drilling of additional holes in developed pools which will hasten the exhaustion of the pools but which will not add materially to the total volume of gas recovered. These new pools may start with a large flow, but as a rule the rock pressure will be low and the volume of gas will decrease rapidly. The effect of new drilling in developed pools was illustrated in a striking way in 1920 by the drilling of some large wells in Allegheny county. Two wells were drilled in Nine Mile hollow in May, 1920. May 6th one well was yielding an open flow of 1,250,000 cubic feet per day. June 17th this well was producing only 150,000 cubic feet. May 20th another well in this area had a flow of 3,000,000 cubic feet a day but was soon drowned out. The same story was being told at that time in a multitude of other gas wells which came in "big" during that winter.

Discovery of New Gas Pools.—The second type of new gas wells are those in new pools, either in pools in the lower sands previously undrilled or in areas not previously drilled. The discovery of the McKeesport pool in a lower sand, the Speechley, in an area dotted with gas wells some of which were 30 years old or more, illustrates the possibilities along this line. That other pools will be discovered in lower sands is to be anticipated, though it is unlikely that other pools as rich as that at McKeesport will be found. During the last few years many holes have been drilled to 4,000 feet or more for the express purpose of testing the Speechley, Bradford and other lower sands. This drilling has, as a rule, shown that the lower sands are less persistent and less reliable than the upper sands and while disclosing much additional gas, does not hold out hope that these lower sands will materially retard the anticipated general decline.

Possible exception to this general condition may exist in the very deep Oriskany and Medina sandstones. The Oriskany sand yields gas where pierced in the Ligonier well at 6,822 feet (8,450 feet, estimated, below the Pittsburgh coal), but

did not yield gas where pierced in the McDonald well (6,100 feet below the Pittsburgh coal) nor has it been reported as present or gas-yielding in the wells drilled through its horizon in the northwest corner of the state.

The Medina sand is supposed to underlie at least all of northwestern Pennsylvania and possibly all of southwestern Pennsylvania as well. This sand has been reached by drilling in Erie county where it has proven gas yielding. It has been reached by a large amount of drilling in northern and central Ohio and has been the source of very much of the natural gas obtained in that state. Its depth in the McDonald well has been estimated at 8,300 feet below the Pittsburgh coal and at the Ligonier well at 10,150 feet.

There still remains the possibility of new gas fields or the extension of present fields to adjoining areas as yet untested. A map of the oil and gas fields shows that gas, in the main, is confined to a belt from 30 to 60 miles wide lying on either side of a line from the northwest corner of McKean county through Pittsburgh to the southwestern corner of the state. Within much of this belt the gas pools are so closely spaced as to suggest that nearly or quite all of the territory has been tested, though doubtless there are many small areas yet untested which will yield pools of gas of some magnitude. In the northern part of this belt there are large areas especially in Forest and Elk counties that are now yielding neither oil or gas. The Survey is not as yet in possession of information which explains why these areas have yielded neither oil nor gas. Until a study of the area has been made, it may be assumed that all of Forest county is possible oil territory and that all of Forest and at least the northwestern half of Elk county is possible gas territory.

Prospecting in the Eastern Part of the Coal Field.—East of a line from the southeast corner of McKean county to the southeast corner of Greene county, is a large area in which are dotted a few small gas pools and which may, therefore, be considered possible gas-producing territory. Fifteen years ago, the present State Geologist was very hopeful that proper drilling would reveal large bodies of gas under the anticlines throughout this large area. At that time, a small gas pool

existed on the western flank of the Chestnut Ridge anticline, and a still smaller pool on the Laurel Ridge anticline was producing gas, but in the main, the test wells drilled up to that time had been in the synclines and, therefore, could not be considered of value in showing the presence or absence of gas. Since that time, however, the structure of most of this territory from the center of Clearfield county southward has been mapped in detail and published, and a number of test holes have been sunk on the crests of the anticlines as revealed by these studies. To date this drilling has yielded only a few gas wells which with one or two possible exceptions are very small. Most of the gas so far found in this area has come from one or the other of two sands, one of which lies about 700 feet below the Brookville coal at the base of the Allegheny formation and the other 1,550 feet deeper.

At present the outlook in this large area is as follows: the Uniontown-Connellsville-Latrobe syncline may be taken as the dividing line between the productive area on the west and the non-productive area on the east. East of that line a multitude of small gas pools probably exist but judging from past experience their finding is likely to involve the drilling of a large proportion of dry holes. Indeed, until natural gas sells at a much higher figure than at present, the cost of prospect drilling in this area is almost certain to exceed the value of the gas obtained (all wells considered) and so to discourage prospecting.

When the price paid for gas and the cost of drilling reach such figures as to hold out hope of adequate returns, drilling should be started on the crests of the domes shown on the structure map or of domes to be shown in reports published in the future.

Outlook in Northeast Counties.—Tioga, Bradford, Susquehanna, Wayne, Lycoming, Sullivan, Wyoming, and Pike. The surface rocks of these counties are mainly the red Catskill shales and sandstones that, in western Pennsylvania, include from the Second to the Fifth or Sixth sands. Beneath these lie the Chemung rocks, the formation which in western Pennsylvania, include the sands from the Elizabeth to the Gartland. Scattered drilling in most of those counties has shown

the presence of small amounts of gas and leads to the belief that gas in small amount may be expected in most of this section of the state. As soon as topographic mapping has covered these counties, it is hoped to make a structural study of the wells that have found gas, to determine if they are on favorable structure or not. If it shall prove that they are, little hope could be held out for larger wells than those already found; but if it shall be found that favorable structures have not yet been drilled, it is possible that much larger gas flows may be obtained. At present only small wells large enough to supply one or two dwellings each can be hoped for.

Among wells in this area which have yielded gas may be mentioned a well drilled near Ramsey, Lycoming county, in 1904. Several gas wells have been drilled or are drilling west of Tunkhannock, Wyoming county. One of these is said to have produced a flow of gas which could be heard for some distance. One was drilled in 1881-1882 to a depth of 2,089 feet. Gas is said to have been obtained in practically all of the wells drilled along Mehoopany creek, Sharps pond, and Cassam brook. Most of these wells were from 1,200 to 1,400 feet deep with a rock pressure of about 850 pounds.

Some gas has been found in Susquehanna county, as on the Wheaton farm north of Montrose, and on the Cahill farm in Middletown township. A well drilled at Narrowsburg, on the New York side of Delaware river to a depth of 800 feet is said to have found some gas.

All of these reports show the presence of gas throughout this area covering several counties. But considering the present cost of drilling for gas and of piping the gas when found, in contrast with the small flows so far encountered, this area does not seem to offer great inducement for prospecting or hope of financial reward.

Outlook in Central and Southeastern Pennsylvania.—This large area lying east and south of the Allegheny front is believed not to contain commercial quantities of oil or gas. Many wells have been drilled within this area and in the corresponding rocks to the northeastward and southwestward in New Jersey, Maryland, Virginia, North Carolina, and other states, so far with entirely negative results. At many

places within this area there are "showings" of oil or gas springs and in a few places many gallons of oil are reported to have been obtained.

The area may be divided for study into four belts: (1) The ridge and valley area containing highly folded rocks which commonly rise out of the ground at angles of from 30 to 90 degrees. The rocks have been slightly metamorphosed so that some of the sandstones have been changed to quartzites, the coal beds turned to anthracite and the black shales, so far as tested, yield no oil on distillation. Some drilling has been done in this area, and a few wells have found enough gas to light at the mouths of the well, but nothing of commercial importance. (2) Southeast of the first belt is the broad valley belt including, at the north and west, the Lebanon and Cumberland valleys. Here the rocks are not only tightly folded but more or less crushed and faulted. Metamorphism has gone farther so that some of the shales have been converted into slates and some of the limestones into marbles. Many oil seepages or springs have been reported, analyses from some of which indicate a white oil very high in kerosene. The presence of these springs has led to some drilling but so far without result. (3) Within the confines of the valley belt is a narrower belt of Triassic red beds, sandstones and shales which have not been folded, crushed or metamorphosed so fully as the enclosing older rocks. They have, therefore, been prospected with much interest as yet without success. The reason for failure here would appear to be the lack of an initial supply of plant or animal remains in the rocks to serve as a source for the oil or gas. A study of the red beds shows almost no bituminous or carbonaceous matter. Here and there are traces of coal which in Virginia and North Carolina become of commercial importance, but, in general, the material of these beds does not appear to have been laid down under conditions favorable for the existence or the preservation of life. (4) The fourth belt consists of the granites, gneisses and other highly metamorphosed and igneous rocks of the southeast corner of the state extending westward into York and Adams counties. In this belt the rocks have been so squeezed, crushed and melted that it is

often impossible to guess their original character. That pockets of oil or gas may have been sealed up in these rocks is not impossible though very improbable, but that any large supply of oil or gas may yet be found in these rocks is contrary to all experience and opposed to all theories of the origin and occurrence of oil and gas which, after all, are built up on experience, the results of which they seek to explain. It is true that this area has not been fully tested. But many wells have been drilled here and there, none of which, so far as learned, has ever paid for itself.

Summary of Outlook for Gas.—The facts given may be summarized as follows: (1) The production of gas in Pennsylvania reached a maximum of 138,000,000,000 cubic feet in 1906 since when it has declined irregularly, reaching 123,000,000,000 cubic feet in 1918, the last year for which final figures are available. (2) The average initial daily production of new wells and the initial rock pressure has shown an even more marked decline. The following figures were published by the Peoples Gas Company, one of the largest in the state. (3) Such figures and a multitude of others show clearly that the present productive gas fields of Pennsylvania are slowly but certainly playing out. The decline is likely to be fairly rapid for a time and then more and more slowly until the cost of maintenance of the wells exceeds the value of the gas, which point may be 100 years or more hence. (4) Outside of the present developed fields there are large areas that, judging only by the surface geological features, should be gas-bearing. These areas may be counted on to retard the decline of gas production but are not likely to stop the decline or reverse it. (5) Far below the sands commonly developed today are two sands known to be locally productive in Penn-

Decline in initial flow and rock pressure of gas wells
(Peoples Gas Company)

	1915	1916	1917	1918	1919
Average initial daily production.........	1,071,073	[illegible],559	462,899	395,870	283,651
No. of wells drilled	50	118	165	137	130
Aver. rock pressure in lbs. per sq. in.....	423	365	249	261	271

sylvania. These sands, the Oriskany and Medina sandstones, may yield large volumes of gas in the future but their exploitation will be very expensive because of their great depth. (6) The prospects for gas decrease in going eastward from the center of the gas field toward the Allegheny front. (7) The counties in the northeastern part of the state are underlain with rocks which are gas bearing on a small scale but do not give promise of large commercial production. (8) No commercial supplies of gas may be expected to be found east or south of the Allegheny front in the central or southeastern parts of the state.

CHARACTERISTICS OF SOME TEXAS SEDIMENTARY ROCKS AS SEEN IN WELL SAMPLES

By Johan A. Udden*

Those who have given sufficient attention to the nature of sedimentary rocks are well aware that these rocks in many cases present minute features that are quite constant for different formations and that such constant features can be used for the identification of more or less extensive strata that may be explored by drilling, if sufficient care be taken in securing samples. Distinguishing sandstone from limestone and distinguishing these from shales, marls and clays is in most cases very readily done. Each of these groups of sediments, moreover, presents a great number of variations, the most conspicuous of which are due to differences in color and hardness. Many of the readily recognizable variations are also due to minor changes in the chemical composition of the materials, and to the arrangement of the clastic elements in the rock. These differences have long been recognized by drillers who have described them as to composition, color, hardness, etc., in their logs of borings. In the last twenty years, geologists have found it necessary to give special attention to these minor, in many cases microscopic, features of sedimentary rocks, in connection with progress in underground explorations, for the purpose of making precise and reliable correlations, extending not only through a single oil field of limited size, but also from one field to another, and in fact, identifying formations anywhere and belonging to any level in the geologic column. In cases where the formations so correlated are inaccessible except from observation of drill cuttings, such studies become important.

In this work it has been found, as indeed has been long known from surficial studies, that certain formations remain very constant in their minute features for hundreds of miles and that reliable identifications of many such formations

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can well be made on the basis of lithology alone. This is said without the least hesitation though of course there are many cases in which it is impossible to make reliable correlations in this manner. In the absence of fossils the paleontologist may be unable to determine the age of a particular formation, though seen in natural exposures. Similarly, in the absence of characteristic physical features and such minute fossils as may be found in drill cuttings, it may be impossible to correlate formations from well samples. The experience of the writer has been that in judging the significance of lithologic characteristics, as in the case of paleontologic investigations, our eyes are sharpened by continued practice. He has also learned that the characteristic features of different formations are only slowly and laboriously recognized by the students who are most interested in the development of this special study. One reason why very little attention has been given to a more formal study of well samples is the prevailing idea that such studies cannot be compared in general worth with correlation studies based on fossils. This notion has very likely also prevented geologists from publishing as much as might have been profitably done, on the physical characters observed. Recognition of formations from well samples is an art that has been acquired by many geologists largely through individual effort. This has been aided in many cases by what we might call "trade lore," communicated through personal intercourse among the devotees of the art.

In the hope that it may be some aid to the profession, the physical characteristics of certain sedimentary rocks in formations which have come under the writer's observation may be described. These have been an important aid in his work, and may help others in recognizing formations explored. The usual order of stratigraphic descriptions, beginning with the earliest sediments and following with the later deposits will be followed. The notes refer exclusively to formations in the state of Texas.

PRE-CAMBRIAN ROCKS

The oldest rocks which have been identified in deep borings far from outcrops, consist of schist and gneiss in the Archean. Several deep borings in the Panhandle have stopped in red gneiss, usually called granite by the

drillers. It may be said to resemble the red granite and gneiss exposed in the Central Mineral Region of Texas. In thin sections the crystalline nature of the rock is evident. From a depth near 3,000 feet in Terrell county, a deep well has encountered a schist of greenish color. This schist is in part very fine in texture. Some of it consists of fine-grained slate of a greenish color. From Montague and Cook counties, on Red river, have come some cuttings representing a schist carrying hornblende and also samples of a rock resembling granite. From several deep borings, perhaps not yet a dozen, located either on the Balcones escarpment or not far from it on either side, have been obtained a number of samples that are remarkably similar in their lithological characters. One almost necessarily comes to the conclusion that these samples represent a single formation. There is a gray quartzite-like rock of fine texture, consisting of angular grains. It is mostly indurated, but in spots it is almost a sandstone. The grains are never large. No pebbles are present. Associated with this quartzite is a slate or shale of very fine texture and varying in color from gray to black. This slate as well as the sandstone is cut by many small veins, some of which are filled with quartz, others with calcite and pyrite; others are again stained black by manganese, and still a few others are open and unfilled fissures. Frequently the veins are straight and parallel. In other cases they are curving and irregular. Another feature which is almost invariably constant is that the black slate, and sometimes also the fine-grained dark quartzites of this formation, yield strong fumes of ammonia on being heated. Some of the dark slate also yields bituminous fumes, but this is an exceptional feature. Several large cores from one of these borings and quite large fragments of the rock from several other localities have been examined. It is evident from the core samples, especially, that the formation has been very largely affected by mountain building forces, resulting in sharp fractures and folds. From the core it is evident that the strata stand at high angles where it was taken. Many slickensides and small faults are to be seen. It is believed that this formation belongs to the Huronian.

CAMBRIAN BELOW THE ELLENBURGER

Only a few borings have extended into the Cambrian below the Ellenburger in the north-central part of Texas. These have encountered glauconite-bearing sandstone and limestone, varying from almost pure sandstone to perfect limestone. The limestone is calcareous and in most cases shows a profusion of shells, which are largely the remains of trilobites. Evidently the original material in these shells has been replaced with calcite. The occasional appearance of tapering spines and plates which come to sharp edges characterizes much of this rock, and causes the thin sections to be unlike anything found in the later Paleozoic series, where trilobite remains are less abundant. Occasionally one can distinguish small fragments of brachiopod valves of forms related to *Lingula*. Occasionally, also, in thin sections one can notice the peculiar latticed appearance of skeletal structures of echinoderms. The

glauconite grains in the Cambrian are bright green and usually not of large size.

ELLENBURGER

This formation may be divided into two parts, a lower dolomitic limestone of coarse texture, which is several hundred feet in thickness and an upper part probably less than 100 feet in thickness which does not contain a sufficient amount of magnesia to be called a dolomite. The lower part is probably Cambrian, while the upper part is known to be of Ordovician age. Few borings have penetrated the entire Ellenburger and most samples examined from the dolomite of the Ellenburger come from its upper 100 or 200 feet. In the lower part of the formation many ledges consist of crystals which measure ½ mm. in diameter. It contains some oolite and considerable white flint or chert. There are also occasional grains of glauconite. In the upper part of this dolomite, a feature has been noted the like of which the writer has never seen in any other dolomite. In some layers of relatively fine texture there occur diamond-shaped crystals of giant size, imbedded in the mass of a much more finely crystalline matrix. Another feature is the development of spherical bodies of minute size, which are surrounded with a crystalline layers of radial structure. This, growing toward the center, may have developed so as to fill spherules, giving them an entirely radial structure. These later structures appear to be most common in the middle part of the dolomite.

The upper part of the Ellenburger consists of a limestone too low in magnesia to be called a dolomite. This rock is exceedingly fine-grained. Some layers where this formation outcrops have been tested as a lithographic limestone. This part of the formation contains a few scattered small fragments of fossils which it has so far been impossible to identify from drill cuttings, excepting perhaps some sponge spicules. Many of the beds are characterized by dappled microscopic texture, which has the appearance of having originated in the manner of a crush breccia. Rounded bodies of variable size lie imbedded in a matrix of clearer texture. This part of the formation does not appear to be represented everywhere. Evidently it was partly eroded away before the deposition of the Bend in central Texas.

PENNSYLVANIAN

Lower Bend shale—The rocks resting immediately on the Ellenburger limestone in the central part of Texas are of variable character and may represent different formations. Over most of the country north from the Central Mineral Region the basal part of the Bend consists of a black shale of quite homogeneous texture. Like the other black shales of the Bend, this contains sponge spicules It contains also some thin layers of oolitic limestone and in places it contains black chert, which may entirely replace it. It is also characterized by the presence of glauconite grains. West of the Central Mineral Region, as in Concho, Menard, and Kimble

counties, there occurs under the Marble Falls above the Ellenburger, a conglomerate associated with red clay, and above this, and under the Marble Falls limestone, in two borings, some gray, hard, and laminated limestone containing many *Fusulina*. This limestone has in part a reddish tinge. It evidently represents a part of the Pennsylvanian, which has not as yet been recognized in exposures.

Marble Falls limestone—The Marble Falls limestone is known among drillers as the "black lime." Most of this formation consists of a rock that might properly be called a spicule rock. It is characterized from top to bottom by the presence of sponge spicules, and in perhaps not less than half of the thickness sponge spicules make up an essential constituent of the rock, possibly in places as much as one-half. When this rock weathers, exposed to the atmosphere, the lime is dissolved and there remains a network of microscopic sponge spicules, which may weigh only a little more than half of an equal block of the original rock. In thin sections it is often observed that the spicules lie parallel along the bedding planes, as if sorted and oriented by gentle currents. Among these spicules are occassionally found foraminifera, such as an *Ammodiscus* almost perfect in its symmetry, a *Trochammina*, *Nodosaria*, and a *Bigenerina*. A critical study of these foraminifera will no doubt some day result in discovery of other related forms. There are present frequent fragments of crinoid stems. These can be distinguished by the lattice formed skeletal structures characteristic of the hard parts of the echinoderms. There are large and round grains of glauconite, showing an unusual olive green color. Now and then one will find also bright green glauconite, but most of the glauconite of the Bend, with a single exception, is different from that in any other formations known to the writer. In some samples this glauconite seems to have been slightly oxidized and varies from the usual green to a dull brown color. It should be mentioned that glauconite grains of the same form, size, and color occur in the Dimple formation in the Marathon Uplift in west Texas. Bituminous material is always in evidence in the typical spicule rock. It is evident that in a sea where such a large quantity of sponge spicules accumulated, the conditions must have been especially favorable for the growth of these organisms. Siliceous sponges are at the present time most common in deep water.

Certain layers in the Marble Falls limestone are not markedly rich in sponge spicules and consist of rock that may be called an organic fragmental limestone, such as characterizes other parts of the Pennsylvanian. The rock also contains glauconite and the most abundant organisms which appear in this limestone seem to be echinoderms, bryozoans, brachiopods, and foraminifera, such as *Fusulina* and *Endothyra*.

Alternating with the limestone and spicule rock in the Marble Falls, there are layers of shale which are always filled with sponge spicules.

Smithwick shale—The development of the Smithwick shale seems to vary greatly in the central part of the state, from less than half a hundred feet to several hundred feet. This shale as a rule contains a slight

amount of fine sand. It has a somewhat characteristic bluish black color and contains lenses of dark gray or gray sandstone. The shale itself shows occasional minute fragments of vegetation. Foraminifera such as *Ammodiscus* are very scarce and only very rarely does this shale contain any sponge spicules except in the basal layers. In some borings the shale is associated with calcareous deposits that are fossiliferous, but it is yet undetermined whether these limestones should be classified with the Smithwick.

Strawn Formation—This formation consists of shale and sandstone, both of which vary in character. Like other Pennsylvanian deposits of this kind, both the sandstones and the silty shales are micaceous and they contain shreds of vegetation such as leaves and occasionally stems of plants. The finer shales in some samples contain foraminifera such as *Ammodiscus* and *Endothyra*. It must be acknowledged that from examination of drill cuttings it is seldom possible to fix very precisely the boundaries between this formation and the Smithwick shale below, or the Canyon formation above. Precise correlation in this part of the Pennsylvanian is difficult to make, whether based upon well records or on drill cuttings.

Canyon and Cisco formations—Opportunities to examine well samples from these formations have been relatively few. Each consists of shales, sandstones and limestones. Conglomerates are observed in the north part of the state which contain pebbles of feldspar as well as flint and vein quartz. The two latter kinds otherwise make the bulk of Pennsylvanian conglomerates. Sandstones and the coarser layers in the shales are always more or less micaceous. The sand is never much worn, and always contains a comparatively large number of grains of flint. The shales vary in color, especially in the Cisco. They are more generally calcareous than is the case in the Strawn. The limestones in both these formations are typically organic fragmental, in which crinoid fragments can invariably be found. Chert or flint is nearly always present in some of the Cisco limestones. In the marly shales as well as in the limestones there are many foraminifera, the most common forms being *Fusulina*, *Ammodiscus* and *Endothyra*. The darker shales and the finer-grained sandstones contain many shreds of leaves and other vegetation. No attempt has as yet been made, because of lack of material, to characterize any special horizons in these two formations. It is believed that in the case of this part of the Pennsylvanian, a critical study of the microfauna will prove to be of special value. Owing to uniformity of geographical conditions throughout the long period represented by these formations, the lithologic characteristics of the terranes, it must be admitted, have so far proved less promising as a basis for stratigraphic recognition than has been the case with many other formations.

PERMIAN

The Permian in Texas has such a large development, especially in the western part of the state, that only brief notes can be given at the present

time on the characteristics of underground samples from this series of formations. In the northwestern part of central Texas, the limestones as well as some shales of the Wichita formation can in places be recognized from the presence of small fragments of bones and scales of fish, and of the skeletons of batrachians. There is also an abundance of ostracods. Some of the limestones here are oolitic. Westward these formations change into shales which become interlaminated with salt beds and with gypsum. These are especially abundant in the Double Mountain beds which contain some oolitic limestones. The oolitic limestones at this level are in part organic fragmental. In the interior of most of the oolitic bodies are organic fragments which have been incrusted with a layer of lime of variable thickness. It has been observed in some samples that the oolitic bodies are flattened, as if they had yielded to vertical pressure. In the so-called "Red beds" of the western plains, small quartz crystals are in evidence in many places which have not been seen except in the Permian "Red beds." In the trans-Pecos country the Permian has an enormous thickness and consists partly of coarse dolomitic limestone and partly of other limestones, shales, and sand. In at least two deep borings it has been possible to identify the horizon of the Word formation, from the fact that this formation is in part highly charged with bituminous material and thinly laminated, being a mixture of calcareous material, fine sand, and clay. Descriptions of the formations of the Permian of the western part of the state from deep borings must await the collection of a greater number of samples as well as a much more intensive study of the material already secured, than it has been possible so far to accomplish.

TRIASSIC

In the western part of the state where drilling is now going on in the Triassic and the Permian, it is everywhere of importance to determine the contact between these two systems. A description of all the characteristics of the Triassic cannot be attempted here. That part of the Triassic which immediately overlies the Permian has a purplish red color, while higher up in the Triassic, 200 or 400 feet, the color of the Triassic is very much like the color of the uppermost Permian "Red beds," that is nearly brick red. The sandstones of the Triassic are lenticular and are present at various levels in the series. They contain much more mica than the sandstones in the underlying Permian. In the sandstones of the Triassic, as well as in some calcareous layers in this formation, the drill frequently encounters fragments of vertebrate bones. Such fragments seldom appear in the Permian on the plains west of the hundredth meridian. Gypsum occurs in the Triassic, but it is much more abundant in the underlying Permian. Another feature which is perhaps as characteristic as anything is the presence of pebbly conglomerates or gravels in the basal Triassic. Some such conglomerates also occur in the Permian, but seem to become less and less frequent in the lower formation

toward the east. Cuttings from the Triassic will here and there show the presence of bright lustered lignite coming from imbedded trunks of trees. These are not known in the Permian.

CRETACEOUS

The entire Cretaceous, with the possible exception of the coal-bearing series in the southwest and west parts of the state, is characterized by the usual presence of small foraminifera such as *Globigerina, Textularia, Cristellaria, etc.* There are very few of the sands or shales in the Cretaceous that are not calcareous. Some non-calcareous shale occurs in the Travis Peak and Glenrose formations. Parts of the Del Rio clay are also non-calcareous. A thorough study of the foraminifera of the Cretaceous will no doubt some day enable us to identify more precisely than at present drill samples from different parts of this series of sediments.

Trinity, or basal Comanchean—It is well known that the basal sands transgress from the Travis Peak into the upper Comanchean series. Nevertheless, they may be characterized fairly well, so as to be recognizable in drill samples. They vary from coarse, bouldery conglomerate to fine sandstones, shales and even to limestones, resting immediately on older rocks. By far the most uniformly developed rock in the basal Comanchean is fine sandstone either quite pure, or mingled with calcareous deposits. These sands are never micaceous and consist mostly of quartz grains. In the calcareous material in this formation, spines of echinoderms of minute size can always be found in addition to some foraminifera. Nearly all limestones in the basal part of the Comanchean carry more or less fine sand. In the central part of the state, conglomerates are frequently encountered consisting of pebbles derived from granite and from the older Paleozoic formations. Pebbles of feldspar and of the Hickory sandstone, as well as pebbles of the Ellenburger limestone have thus been identified.

Glenrose formation—The Glenrose consists mainly of limestone with alternations of marly clays. In thin section these limestones present the usual appearance of limestones of the Cretaceous, disclosing an almost universal presence of small foraminifera and one or two smooth shelled ostracods. The latter are common in marly layers of the formation. In addition to the smaller foraminifera there is generally distributed in this formation the tests of *Orbitulina texana.* These are usually entire, but also frequently broken. They may, very probably, be regarded as a dependable marker of this formation in well samples. One characteristic of the limestones of this formation is the presence of minute dark specks which appear in some cases, if not everywhere, to be due to pyrite. Some layers in the lower part of this formation are dolomitic and some other layers are oolitic, but the oolitic texture is obscure and the oolitic rock contains also many unencrusted minute organic fragments. It may be mentioned as a special feature that in two or three cases the fruits of a *Chara* occur either in the Glenrose or in the Travis Peak. In both of these

formations, lignite may occur. This comes from imbedded, flattened trunks or branches of trees that are sometimes imbedded even in limestone.

Edwards limestone—In the central and southern parts of the state, the Edwards limestone makes the strongest and best developed limestone in the Comanchean. The formation contains several varieties of thick-bedded limestone. One of these is almost a crystalline limestone. Another is an oolitic phase of limestone in which foraminifera resembling *Trochammina* are found partly encrusted as oolitic spherules. This makes the rock resemble in thin section some limestones in the Permian. Other layers in the Edwards are of the typical Cretaceous limestones, consisting of foraminiferal ooze. Still other layers consist of shell breccia. At several horizons the formation is quite porous, and it contains almost invariably several layers of hard gray flint. Owing to the coarse crystallization of parts of this rock, it may be said that calcite is a characteristic of some cuttings from this formation.

Del Rio clay—This formation can sometimes be identified by its non-calcareous nature. Indeed the writer knows of few other clays in this part of the Cretaceous section which are non-calcareous. The formation frequently exhibits streaks of sand which are apt to show in the samples. It also contains considerable pyrite which is in places oxidized. The crystals of pyrite in this formation are very generally of the cubic form. The best markers of the Del Rio clay are *Nodosaria texana* and *Exogyra arietina*. With the finding of both of these fossils there can be little doubt as to the identity of this horizon. Both are often brought up in drill samples.

Buda limestone—This limestone is readily identified by its exceedingly fine texture, which it maintains uniformly for several hundred miles in the southwestern and central parts of the state. A thin section of this rock does not appear to differ materially from that of the usual limestones in the Comanchean, except that the ground mass is finer and more compact. The rock is readily distinguishable by its almost invariable white color and fine texture. It is the most uniformly fine-textured limestone in the Cretaceous series.

Eagleford shale—The Eagleford varies from a series of sandstones, marl and limestones in the northeastern part of the state, to a flaggy limestone in the trans-Pecos country. It has a thickness of some 600 feet in the northern part of the state, only 40 feet in the central part and from there it increases to about 700 feet in Brewster county. With these variations it is almost impossible to give any general characterization that may be made out in drillings. Except in the extreme northeastern and western parts of the state, fish scales and other fish remains are so generally present in this formation that they form a ready means of identification in many cases. The rock consists of a varied admixture of very fine sand, clay and lime. In many places it contains pieces of imbedded tree trunks of small size. These appear as minute lignite fragments in the cuttings. There is a great diversity of foraminifera. The

fish scales can usually be recognized as thin, amber-colored plates, even where the entire scales are absent. In the southwestern part of the state, this formation contains some layers that are black from bituminous material. In the region of San Antonio, drillers are accustomed to call this black rock "lignite." For the first time in the column of the Cretaceous, *Inoceramus* appears in abundance, and the cuttings seldom fail to show the presence of vertical prisms from these shells. This is an aid in distinguishing the Eagleford from the rocks below it. *Inoceramus* continues upward through the entire Upper Cretaceous. It should be added that the Eagleford is almost everywhere a bituminous rock. The more highly bituminous layers in the central and western part of the state can sometimes be recognized from the fumes of the bitumen, which is believed to contain some ozokerite, as it nearly always gives the odor of rubber when heated. The Eagleford contains several layers of bentonite of extremely fine texture, and fragments from these may occasionally aid in identifying the formation.

Austin chalk—This is a very well defined formation, but so far no particular lithologic or micro-organic characteristics have been detected in which much reliance can be placed for its identification. Its softness, dullness of color, nondescript fracture, and above all its unique general appearance as yet furnish the best basis for its identification. *Inoceramus* shells are universally present and perhaps more abundant in this formation and in the lower 200 feet of the overlying Taylor marl than in any other part of the Upper Cretaceous. In places, the white color of the chalk is wanting and in such cases it is sometimes difficult to tell where the chalk really begins. In thin sections of the chalk, tests of foraminifera are always present in abundance. So far as the chalk in Texas is concerned, entire tests of foraminifera make only a small part of the mass of this rock. This is perhaps one reason why the chalk in Texas has a more stony character than in Kansas and Nebraska. In the basal part of the chalk there is in many places some glauconite.

Taylor marl—The Taylor marl is a calcareous, somewhat indurated clay, rich in foraminiferal remains. Cuttings invariably contain brisms of *Inoceramus* shells. Near the middle part, spines of small sea urchins are frequently found in the cuttings and in the lower 200 feet are some admixtures of hydrated volcanic dust, which when pure can be called bentonite. In the upper part of the Taylor marl fish teeth and fish scales are sometimes noted. Identification of this formation must as yet be based upon its general features and our knowledge of the region where the observations are made.

Navarro formation—The Navarro differs from the Taylor in containing more sand and in being more generally glauconitic than the Taylor. This also is a formation without well marked and constant physical features. Near San Antonio it contains some sandstones that are very rich in glauconite, so as to color the returns from the drill a strong green.

Anacacho limestone—This formation replaces part of the Taylor and

perhaps a part of the Navarro in the Uvalde country. It has been identified from well borings as far east as Atascosa county, and the east line of Medina county. It is an oolitic and granular limestone, being a shell breccia in which some of the organic fragments are incrusted in an oolitic shell. Many foraminifera which are quite abundant in this rock, are also similarly incrusted.

Escondido formation—A sufficient number of samples has not as yet been examined to justify a statement of the characteristics of this formation as they appear in cuttings. The formation consists mostly of calcareous shale or clay. It contains many large concretions and also some lenses of oyster breccias in its upper part, evidently resulting from the growth of oyster banks in the water in which this formation was laid down.

TERTIARY

The writer has had but little opportunity to study cuttings from the Tertiary and these rocks can here be treated only briefly. The Midway presents different phases in different parts of the state. To the south it consists mostly of impure limestones and of dark marly clays of fine texture. These clays nearly always contain many foraminifera. Farther north, as on the Brazos and beyond, the Midway contains much limestone. This is generally a coarse organic breccia, rich in foraminifera. The marly clays of this formation have a peculiar blotched dark color. At some levels in this formation it contains dark nodules of phosphate evidently the remains of fishes. It is not impossible that workable beds of phosphate may yet be found in this formation in Texas. Most of the dark shales in the Midway are bituminous.

The Wilcox and the Yegua can usually be identified by their lignite beds. The Claiborne group and the Wilcox each contains some clays and sands that are glauconitic, and it should be mentioned that this glauconite can in many cases be known by the relatively large flattened and oval grains it contains. They exhibit a lobed or coarsely reticulated exterior, evidently impressions of septae in the tests in which they were formed. Foraminifera occur in most of the post-Midway Eocene, and it is believed that these will be of great aid in correlating well samples, when they become sufficiently well known. Cushman has thus recently identified some nummulitid forms recently found by Pratt, in two borings on the Gulf Coast. In one case at least, these occur in great profusion in a limestone. Should this limestone be sufficiently extensive and maintain its character, it will be an excellent formational landmark. There is another feature in the middle and upper Tertiary which should receive our close attention and that is some beds of volcanic dust which it contains. These can hardly fail to have large areal extent and are readily recognized owing to their usual light color and their fineness of texture. They settle in water with extreme slowness, and after drying absorb water very rapidly. These are the layers of so-called "bentonite," which also frequently are spoken of as fuller's earth deposits. We should note the levels

where these beds occur, for with an accumulation of such data, they should in time aid greatly in making and verifying correlations. We also have a diatom-bearing clay in the Miocene, which should be observed closely. In a boring made some years ago near Karnes City, the drill passed for some two hundred feet through a clay containing many diatoms, mostly large and spherical in form. So far as known this clay has not been noted in any other boring on the coastal Tertiary, though it very likely is widely distributed and can readily be identified. The DeWitt formation of Miocene-Pliocene age, can in many places be recognized by the presence in the cuttings of fragments of mammal bones, though such bone fragments of course also come from Pleistocene deposits. They are however, most frequent in the DeWitt.

PLEISTOCENE

Only very few borings in the Pleistocene on the Gulf border have come to the writer's attention. Nearly all sands and clays in this series contain sometimes worn, and sometimes well preserved tests of foraminifera derived from the Cretaceous and the Tertiary. In places, these are mingled with Pleistocene forms. As a curiosity, perhaps it may be mentioned that *Chara* fruits were noted at a depth of some 900 feet in a locality close to the coast. It is to be regretted that so very little material has yet been collected from our latest deposits on the Gulf Coast.

CONCLUSION

This is a brief review of a part of the lore gathered by those who have taken time to examine samples from deep borings in the southwest. It is not intended to be at all exhaustive, but it may be a help to some geologists who need to make such examinations. Two earlier papers briefly described the methods that the writer employed in making examinations of this kind. It is impossible to make examinations as exhaustive as they should be. Time will seldom allow this. If the writer should briefly describe his methods, as he has been asked to do on several occasions, he might say that on all samples such observations are made and such notes are taken as can be done without too much loss of time. Fossils are determined only as to their resemblance to genera, or other larger groups. When occurring in sufficient abundance they are stored away to be referred to specialists who can study them at leisure. This part of the descriptions, nevertheless, characterizes roughly the microfauna which exists in any particular formation. Sands and conglomerates are described according to their mechanical properties. As far as possible, notes are taken on the ingred-

ients of different kinds of materials and on rocks represented. Argillaceous rocks are treated in a similar manner. In addition such observations are made as may be possible, on bedding and on characteristic minor ingredients, like sulphur fumes, bitumen and ammonia. Limestones are most profitably studied in thin sections, in which their texture, and the original material from which they were made can be determined. Tests for volatile ingredients are also made on limestone, whenever this may seem desirable. There is a great variety of limestones representing a great variety of physical conditions. Our ultimate object should be to make full and exhaustive descriptions of every feature that can be observed in each unit of sedimentation. This will require the work of a great number of geologists for a long time to come. We must take time for studying more intensively the nature of the clastic rocks. It is now quite generally recognized that studies of this kind promise ultimately to aid greatly in making out the physical conditions in the earth's past history, such as they were at the time and in the place where each formation was made.

DRILLING OIL WELLS WITH THE DIAMOND DRILL

BY FRANK A. EDSON*

Every one who studies conditions in the petroleum industry realizes that if the production required by the modern world is to be maintained the time is rapidly approaching when new production must be sought farther afield and where drill locations are less promising. This means that the cost of wild-catting will be increased, for the cost must be borne by the new production thus discovered. In 1919, 60 percent of the wildcats drilled in Oklahoma produced either oil or gas. If only 40 percent are productive this year it is obvious that the cost will be increased 50 percent. The very fact that the most promising locations are being rapidly drilled up, means that the cost is bound to rise.

To meet this increased cost of wildcat wells, the operator has two different methods of attack. One is that of cheapening the cost of all drilling by paying a smaller wage scale and by purchasing his materials at a lower cost. The present wave of readjustment will undoubtedly bring this about to a considerable extent, but it is also possible that this readjustment may bring a fall in the price of crude oil.

The other method of attack is by more efficient drilling, by getting more value out of the money spent in wildcatting, so that while the cost may be approximately the same, the amount of information is greatly increased and thus more value is obtained for every dollar spent. In the belief that he has found such a method by adapting the diamond drill to the drilling of oil wells, a method which will certainly give much more information and which will probably be somewhat less expensive than the present methods, the writer presents in this paper the principal facts about diamond drilling for discussion by the oil fraternity.

In order that its efficiency may be clearly understood, it is probably desirable to give a brief description of the drill and

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the method of operation. The diamond drill consists of a line of hollow steel, flush-jointed rods screwed together in sections, as is the drill stem of a rotary drill. These rods are rotated by an engine through shaft and gearing, and are fed downward by the pressure of a hydraulic cylinder which is capable of exerting a pressure of several tons either upward or downward. At the lower end of the rods a hollow core barrel is placed. On the end of this is an annular or ring-shaped bit, in which are set actual black diamonds, and which as the rods are rotated, cuts an annular hole in the rock, leaving undisturbed in the center a solid cylinder or core of rock. Water is kept circulating through these rods to keep the bit cool and to wash away from it the cuttings and bring them to the surface. The essential feature of the drill is the hollow bit which cuts the core. When enough core has been cut to fill the core barrel, the rods are withdrawn by means of a hoisting machine, bringing up with them the bit and core, the latter being caught and held by a self-locking core spring. The core is removed from the core barrel, the rods lowered again, the process repeated until the desired depth is reached.

While the diamond drill resembles in many respects the rotary, it also differs in some important points. It does not attempt to pulverize the entire area of the hole, but only enough to allow the bit to advance. The downward movement of the bit is controlled by the action of a hydraulic cylinder, instead of the pull of gravity. This pressure, amounting in the larger sized outfits to over 30 tons, can be exerted either up or down, while at the same time practically the full hoisting power of the engine can be utilized. This feature will be appreciated by every man who has ever had a rotary bit stick. Clear water is ordinarily used instead of the mud laden fluid of the rotary drill. Thus the cuttings are not obscured when brought to the surface, and the formations can be identified readily. Since clear water circulates much faster, the cuttings from a depth of 3,000 feet will be brought to the surface in about five minutes. However, the diamond drill can use the same mud laden fluid as the rotary if desired. This would only be advantageous in unconsolidated ground like that found on the Gulf Coast.

This additional point should be kept in mind. The diamond drill is at its best in the harder rocks. The writer has seen sandstones which the northern type of churn drill would hardly touch, drilled at the rate of over 100 feet per hour. Granite can be cut at the rate of 20 or 30 feet per day, and limestone much faster. Hard shales and soft slates can be cut at about 12 feet per hour. The diamond drill has no rival when speed of cutting is the only consideration. The feature which gives the diamond drill its great advantage as a means of obtaining information, is the core. By its aid the operator can tell the exact condition of the rocks which the drill penetrates. It is just as true a sample as if it had been taken from the original outcrop. A better sample could not be obtained by sinking a shaft. By methods which have been in use in the metal fields for years, it is possible to measure the porosity to a fraction of a per cent. The amount of saturation can also be determined to a much finer degree than is possible at present. From this, which the operator can actually observe, he can obtain a much better idea of the probable amount of oil to be obtained from a given rock, and so be informed in advance as to how expensive an installation is justified. It is very possible that a parting will be found between the oil sand and underlying water. This parting may not be a shale but may simply be a close cementation of the sands. In either case, the diamond drill core will show it, and will give its position and thickness, not simply to the foot, but to the exact inch. If igneous rocks are encountered, the core will show whether they are a solid dike or sill, or simply a mass of boulders and arkose from some ancient mountain peak. Briefly, the first diamond drill hole in a new district will give more information about that district than almost any number of holes drilled by ordinary methods, and some of this information will be data which are not available in the oldest oil field on the continent. The writer realizes that these are strong statements, but he knows that any engineer who has had experience with the diamond drill will corroborate him.

The diamond drill is not a new and untried tool. It has been in use in the coal and metal fields for over fifty years.

All the problems in regard to drilling oil wells by the diamond drill have been worked out with the exception of the size of the holes. The rocks which compose our oil fields are practically the same as those from which the diamond drill has removed satisfactory cores for years in the coal fields. The depth brings no unsolved problems because the diamond drill has already gone to approximately 5,000 feet in Oklahoma, and to over 6,000 feet in South Africa. The question of increasing the size of the hole brings in no new mechanical principles. The manufacturers stand ready to build and operate these larger sized machines as soon as they are assured of a demand.

The diamond drill uses flush-joint casing instead of the ordinary kind. There are two reasons for this. The first is that a string of flush-joint casing can be carried farther, other things being equal, than can the ordinary type of casing. With the latter there is a decided tendency for the dirt and sand to ball up under the couplings. If the lines of force which are thus produced, are diagramed, it will be seen that the effect is that of a truss, similar to the design used in supporting bridges. This effect is entirely eliminated with flush-joint casing, and the limit to which it can be carried is determined solely by the side friction on the casing, unless the hole is so deep that tensile strength becomes a factor. The second reason is that by the use of flush-joint casing the diamond drill is enabled easily to shut off water sands without being compelled to land the string of casing and reduce to a smaller size to continue the hole. The method followed when a water sand is encountered is as follows. The sand is first drilled through with the ordinary bit, and the hole is then underreamed to a diameter an inch or so greater than the outside diameter of the flush-joint casing. This underreamer is expanded by hydraulic pressure, cuts by rotary action and automatically folds together when the water pressure is removed. The hole is then cemented to a point a little above the top of the sand. By using the full pressure of the pump, the cement is forced back into the sand as far as possible. As soon as it has set sufficiently, the cement is drilled out with the ordinary diamond bit, and then underreamed just enough to allow the

smooth flush-joint casing to pass through. Thus a collar of cement, about an inch in thickness, with its outside edge thoroughly imbedded in the sand, is extended all the way through the water sand. Thus the diamond drill escapes the necessity of having to set a string of casing whenever it is desired to shut off the water. The same method can be applied equally well to a gas or oil sand. This absolute control of upper sands is one of the strong points of the diamond drill.

Since each string of casing can be carried farther, so many strings of casing are not required as in cable tool work. Moreover, the strings which are eliminated are the larger and heavier sizes which are the most expensive ones. The saving on casing will, under ordinary circumstances, amount to about 60 per cent.

Labor costs on a diamond drill are less than with the other types. The crew required to run a diamond drill on a 3,000 foot hole is composed of six men, three per tour or shift. The wages of this crew would amount to not over $35 or $40 per day. The other costs are in somewhat the same proportion. The diamond drill uses about 8 barrels of fuel per day, the other types consume from 16 to 20 barrels. The diamond drill uses from 50 to 150 barrels of water per day, depending on the nature of the ground in which it is drilling. This is a little under what the standard will use, and much under what the rotary requires. The cost of the rig is from $500 to $700 less than a standard rig, as many of the rig irons of the latter are not required. Transportation costs are materially lessened, not only by eliminating the larger sizes of casing, but also by the smaller weight of the outfit itself which is not over 30 tons for an outfit capable of drilling a 4,000 foot hole. Diamond drill rigs do not need to be purchased by the operator; they can be rented at $35 or $40 per day. Such an outfit is complete in every particular, and the manufacturers will also supply competent drill men who will have to be paid as stated above.

The weak point in the diamond drill is the time required for drilling, for it will not average over 40 feet per day in the deeper holes. As has been pointed out, the actual speed of cutting is much greater than with either of the other methods,

but so much time is lost in raising and lowering the rods in order to empty the core barrel, that it is probable that the average speed would not be above the figures given. Taking everything into consideration, the cost of diamond drilling an oil well in the Mid-Continent field, for example, should not be less than $4.00 nor greater than $13.00 per foot, depending on the depth of the hole and the nature of the ground encountered. It should be clearly noted that these figures cover complete costs, including casing, fuel, and water, and that they contemplate reaching the desired depth with a hole at least 4 inches in diameter—a hole big enough to be pumped and not simply an exploration hole. These latter, of a diameter of 3 inches or less, can be drilled for from 60 to 75 per cent of these figures.

The action of the diamond drill can be speeded up to a surprising extent if no attempt is made to take core. There is a special type of diamond bit, called the "plugged" or solid bit, made especially for this purpose. In this form the bit has a solid concave center, which is studded with diamonds. This center is screwed into the regular bit about an inch or so above the bottom, and is pierced with holes to allow free circulation of the water. The small stub of rock projecting up into the bit is attacked on all sides by the diamonds and by the force of the water jetting through the small holes in the bit, and is readily ground up and washed away. In very hard rocks it is not a practical bit, for the diamond loss is too large, but in soft sedimentaries it is very practical indeed. Some surprising speeds have been attained by its use. Diamond drill men have told the writer of drilling over 100 feet of limestone in a little more than four hours by the aid of this bit. Its use, or the practise of grinding up core in the core barrel, in the upper part of the formations, where the special knowledge that might be gained from the core is of little importance, will speed up the drill and cut the cost of operations very greatly. The diamond drill is the fastest method known in so far as the actual cutting of the rocks is concerned, and there is no reason why full advantage should not be taken of this speed in going through formations like the Permian "Redbeds" where knowledge of the strata is of

no particular importance, and no attempt need be made to take core until a critical depth is reached. Incidentally, there is no particular reason why the regular fish-tail bit used by rotary drills should not be used on the diamond drill when rotary ground is encountered. There are no mechanical difficulties in the way. It is the writer's judgement that the cost figures given above can be cut from 40 to 60 per cent, which would make the diamond drill a very serious competitor of the other methods for the drilling of all wells.

There are two ways in which the diamond drill can be used to advantage on wildcat work. The first, which has been discussed, is the drilling of a regular oil well by this method. This is probably advisable, regardless of cost, in an absolutely virgin field where it is important to get all available data. A variation of this method is the drilling of a small sized prospect hole to find out whether the formations are petroliferous. If oil is found in this hole, other holes can be drilled by any method the operator may choose.

The other method is to drill a full sized hole down to the sand by regular methods, and then drill a small sized hole through the sand with the diamond drill. This is similar to the "rat-tailing" which is done by the rotaries, but is less expensive and more satisfactory. The onlv extra equipment needed is a line of three inch casing down to the sand, which can be set at the same time the regular casing is set. This casing is necessary in order to give the water sufficient speed in its circulation so that it will bring the cuttings back to the surface. The casing can be removed readily when the diamond drilling is finished, and the hole afterwards drilled out to full size by regular methods. This method obtains a two inch core through all the oil sands, which is ample to show their nature and texture, the position and nature of any partings and will also give valuable data as to whether or not the well should be shot. It is probable that these small holes can be bailed out best by using compressed air. The cost of such diamond drilling will vary from $500 to $2,000 depending on the depth of the hole and the amount of drilling necessary.

To put it briefly, it is believed that the diamond drill affords

a means of obtaining much more accurate information than either of the regular methods, at a cost no greater than that now paid for much more meagre information obtainable from the regular methods of drilling. In other words, the diamond drill will give the operator larger value for the money spent, and therefore, is worthy of serious consideration by the oil fraternity.

DEBT OF GEOLOGY TO THE PETROLEUM INDUSTRY

By E. DeGolyer*

It is particularly fitting at the present time, that we petroleum geologists,—men interested chiefly in the application of our science to the economic problem of petroleum mining—should turn for a moment from the problem of what success the science of geology has had in this particular field to a consideration of the impetus and advancement, if any, which the industry has given to the science.

During past years, in giving consideration to the general condition of their profession, most petroleum geologists have felt impelled to defend their position in the industry,—to argue the value of applied geology in the exploration and exploitation of oil deposits. This is no longer necessary. The desirability and need for a rational use of applied geology in the best modern oil field practice and the lessened hazard to capital resulting from such use are established beyond debate.

At present, however, the most important criticisms leveled against our profession, directly or by implication, have come from our scientific colleagues,—geologists not engaged in economic work.

These criticisms range from the low valuation placed upon much of our economic work, an appraisal more or less merited when judged solely by the standards of scientific surveys, to the exaggerated innuendos of the more virulent of our "holier-than-thou" brethren from which one might easily conclude that we are, as a class, altogether untrained, inexperienced, and without standards, the pariahs of the profession. Nor is this dissatisfaction with us lessened by the disproportionately high salaries paid for economic work as compared with those paid for scientific work. A comparative youngster, unheard of as to scientific achievements and publications, may receive a salary greater than that of the direc-

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tor of the federal survey,—several of them do receive such salaries. Perhaps some petroleum geologists are overpaid. Certainly most geologists engaged in purely scientific work are greatly underpaid.

In answer to the general criticisms of our work as geologists, it should be said that it is unfair to judge it altogether by scientific standards. It is intended solely to satisfy economic requirements and its scientific results, generally present to some degree and oft times of no mean magnitude, are distinctly a by-product.

A petroleum geologist often maps the structure of areas whose stratigraphy is excellently known from regional studies. If he can distinguish the beds with which he has to work and can determine their relation to each other, he will be able to complete his work satisfactorily.

The only scientific result of work of this type described is information as to the structure, generally a rather insignificant contribution to science and one often lost because it is not published. The geologist may have found a particularly interesting fossil horizon, however, and in such event his find could easily be of the highest scientific importance but it would still be altogether a by-product of his real work. It is as unfair to criticize work of this structural type because of the paucity of scientific achievement as it would be to criticize the work of a paleontologist in the same region because he knew nothing of an anticline a mile broad and with a five-foot closure.

As to salaries, the petroleum geologist in commercial work is engaged in work which gives definite tangible results in an industry which is fiercely competitive and in which successful operations are extremely profitable. The scientific geologist is engaged in surveys or in teaching or research in the universities and museums,—the results of his work are for the most part of indirect application and often of doubtful or of future economic value and its profits to the institution which he serves, if there should be profits, are generally indefinite and intangible. The commercial enterprise has greater reason as well as greater ability to give greater rewards. The petroleum geologist is a producer.

The purpose of the present paper is to take note of this criticism of the work of petroleum geologists by geologists engaged in purely scientific work, to call attention to very distinct and important contributions by the petroleum industry to the progress of the science of geology and to suggest further contributions.

It is difficult to estimate the proportion of geologic work which is being carried on at the present time at the expense of the petroleum industry. In a recent conversation with an eminent geologist from the Pacific Coast who is engaged solely in scientific work, the writer ventured the opinion that 80 per cent of the geological work being carried on in the United States at the present is being done on behalf of the petroleum industry. He replied that he was not well enough acquainted with other regions to express an opinion but that he believed that 90 per cent of the geological work on the Pacific Coast was being carried on by the petroleum industry and only ten percent by other agencies but that, in his opinion, the contributions of petroleum geology to the fundamental progress of the science amounted to about twenty-five per cent and that of other agencies to about seventy-five per cent. In other words, from the standpoint of the geological sciences, our quantitative rating is about ninety percent but our qualitative rating is only some twenty-five per cent. One would like to be able to dispute this conclusion but it is doubtful whether it can be done at present.

The petroleum industry has served the science in many ways. It has given a considerable impulse to the study of geology in the schools and universities. It has, by its continual demonstrations of the usefulness of applied geology, established a respect for that science among laymen. It has by these same demonstrations of utility, enabled state and federal surveys to secure appropriations so essential to the continuance of their work. It has developed field methods, particularly those used in structural mapping of a refinement previously unknown and still unequalled in general geology.

The most important contributions of the industry to the science, however, are those of fact. The geology of thousands of square miles of the earth's surface have been worked

out in detail by competent geologists at the expense of the petroleum industry and many of the results have become available to the geologist engaged only in scientific work. This is true of the United States and particularly true of many foreign areas regarding which we should have had little or no information but for such work. Work has been done in Mexico, Central America, South America, the West Indies, Africa, Persia, and doubtless many other areas, which would not have been done for generations but for the requirements of the petroleum industry.

Eminent scientists, stratigraphers, physicists, and paleontologists have been commissioned to carry on investigations of the greatest importance from a scientific as well as economic viewpoint but which would not have been possible otherwise for many years.

Contributions of the foregoing types involve, of course, a mutual indebtedness. The industry is of value to geology because geology is of value to the industry. Any attempt to strike a balance here must show a credit to geology.

The direct contributions of the industry not concerned in this mutual indebtedness are of the greatest importance. The writer refers to the enormous quantity of information, not otherwise obtainable, which has become available through the drilling of wells in search of oil and gas. Each well record is a geologic section of from a few hundred to several thousand feet in thickness and there are thousands of sections from regions where, from the surface alone, it would be difficult to measure a consecutive section for more than a few score of feet.

On the basis of these sections, the most detailed studies of the variation in conditions of sedimentation over wide areas have been made and the detailed underground structure has been determined to a degree of refinement not otherwise obtainable.

Our knowledge of certain extremely important geological features such as the crystalline floor and buried granite ridge of Kansas, the salt domes of the Gulf coastal plain and other areas, the buried westward extension of the granite knobs of the Wichita Mountains, the curious pre-Pennsylvanian

floor of the Red River area, the buried igneous masses of Thrall and Furbero, and the San Diego-Potrero ridge of Cretaceous limestones in Mexico, is derived almost wholly from the logs of wells drilled in search of oil or gas. One might extend this list considerably but the examples given are sufficient to demonstrate the importance of the direct contribution of fact.

In conclusion, the writer has but one plea to make,—that is for greater attention by petroleum geologists to the scientific by-products of their work and for freer publication of such results as they have obtained as soon as publication may safely be made without detriment to the economic advantages resulting from exclusive ownership of the information. Publication should be regarded as an obligation which we petroleum geologists owe to the science of geology upon which our profession rests. Non-publication is generally blamed upon the executives of the companies for which the work has been done but it is the writer's opinion that non-publication is more generally the result of procrastination or laziness on the part of the geologist than of difficulty in securing permission to publish. From an economic standpoint, the opportunities arising out of most of the work of a petroleum geologist is of a great deal more transient nature than is generally realized. Most companies are liberal with regard to publication and more of them would probably be so if geologists would go to the trouble necessary to secure a consideration of such results as might follow publication.

Publication is our best method for an exchange of ideas and geologic science including its specialized branch of petroleum geology can only go forward as the best results and conclusions of our individual work are made generally available. You may think that you have some particular problem solved satisfactorily but it may be that if your ideas were presented for discussion, you could be shown fundamental errors in your solution. The writer has had such an experience.

Publication is the best policy .

CORRELATION OF THE "WILCOX" SAND IN THE OKMULGEE DISTRICT WITH THE OSAGE, OKLAHOMA

BY LUTHER H. WHITE* AND FRANK C. GREENE**

INTRODUCTION

The correlation of the "Wilcox" sand in the Okmulgee and Osage districts, Oklahoma, here presented is based upon two cross sections and a study of well logs. Plate 1 shows a cross section running in a north-south direction through Range 10 East. Plate 2 shows a similar section through R. 12 E. These sections extend from T. 12 N., in Okfuskee and Okmulgee counties to T. 22 N., in Osage county, the length of each being, therefore, about 65 miles.

In selecting the logs for these cross sections the writers chose wells which were located as nearly as possible in a straight line due north and south. The purpose in this is to show the stratigraphic changes which take place in a north and south direction. However, a work of this kind is limited by the number of deep wells that have been drilled in the area. This made it necessary to deviate from a north-south direction in places as is shown by the diagrams which give the respective locations of the various wells in the cross sections. The logs are given as reported by the driller, no attempt being made to construct a composite log for the different areas. If this were done a much smoother looking cross section would result but that would not seem to be quite so honest and unprejudiced a representation of the facts, especially if the imagination of the writer happened to differ from the imagination of the reader. The arrangement of the logs in these cross sections is such that the base of the "Oswego" lime falls on a straight line. This seems to show the changes taking place in intervals better than to arrange the logs on a sea level datum.

It was not the original intention of the writers to enter

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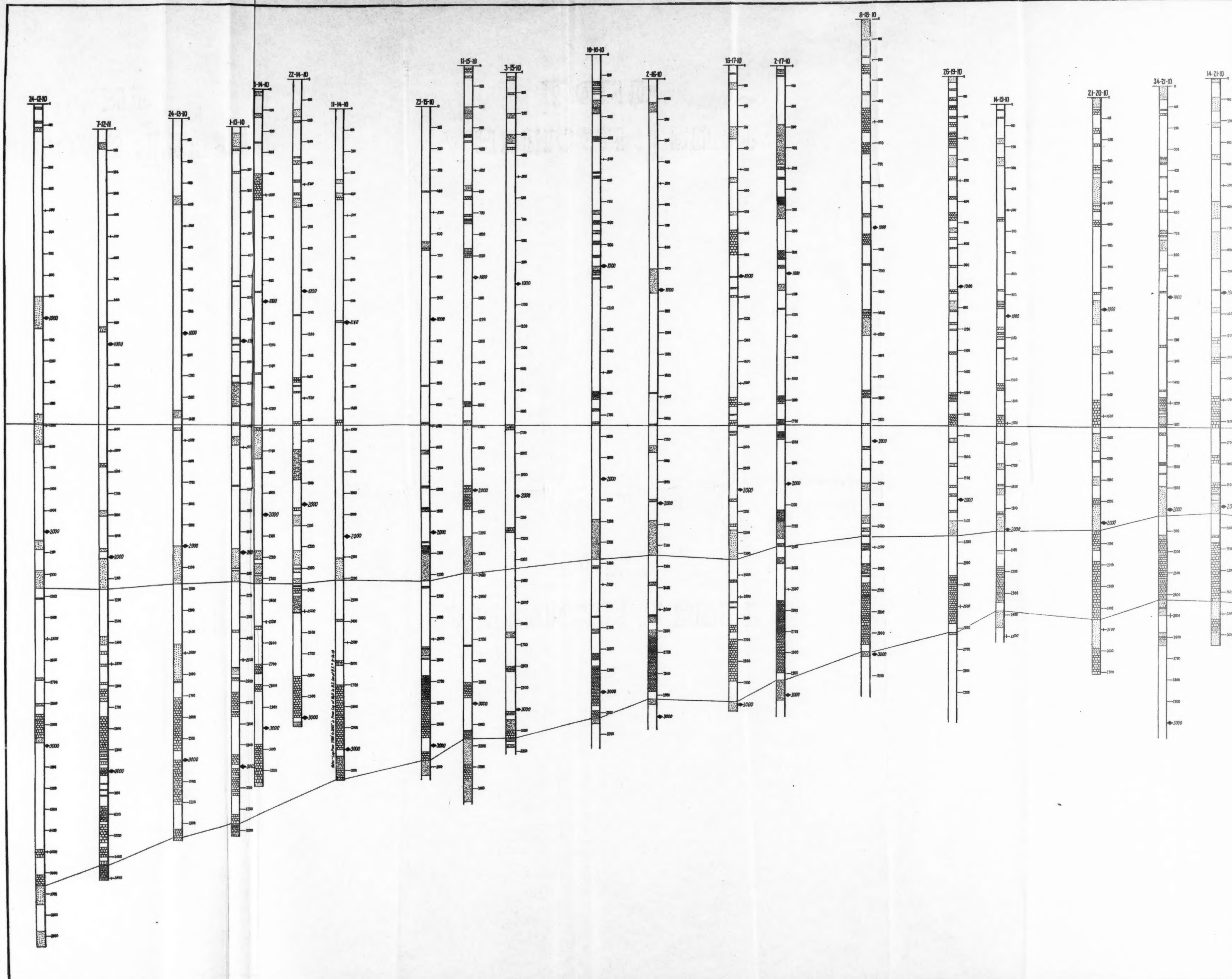
into a lengthy discussion of the general stratigraphy of this region, but certain observations on the formations above the "Wilcox" sand have an important bearing on the subject. This was very forcibly brought to attention when the cross sections began to take form. Some of these problems were solved prior to making the cross section, others remain to be solved. The identification of any key bed over the whole area brings up several questions. In the northern part of the area the top or bottom of the "Oswego" lime makes a good marker, while in the southern part, the base of the "Glenn" or "Salt" sand is the only reliable marker. If the relations between these horizons were constant, the problems would be greatly simplified. The relation of the different formations to each other and to the "Wilcox" sand will be taken up from the top downward, beginning with the Checkerboard lime.

CORRELATIONS

Checkerboard Lime—From Beggs to Tulsa and beyond, the Checkerboard limestone is persistent along the outcrop and is about 2½ feet thick. It is found in logs throughout the northern half of the area under consideration. In the latitude of Tulsa it is 450 to 500 feet above the "Big" lime, the interval decreasing to the north and increasing to the south. In the latitude of Henryetta it is about 610 feet. The interval includes among other sands, the Layton and Cleveland of certain areas, and is the equivalent of the Seminole conglomerate, Holdenville shale, and part of the Wewoka formation of the Coalgate quadrangle. The disappearance to the south takes place about where the underlying sandstone takes on a conglomeratic texture.

"Big" Lime—In the southeastern part of Osage county and vicinity the "Big" lime is a well defined limestone 50 to 150 feet thick. It is typically developed in Ts. 19 to 22 N., Rs. 12 to 13 E. Both south and west of this district it becomes irregular in thickness and locally, as in the southeastern part of T. 19 N., R. 12 E., is sufficiently sandy to produce oil.

The writers do not feel justified in trying to draw correlation lines for this formation in the cross-sections even at their northern ends. As will be shown below the upper part of the "Oswego" lime is rather uniform and there is little diffi-



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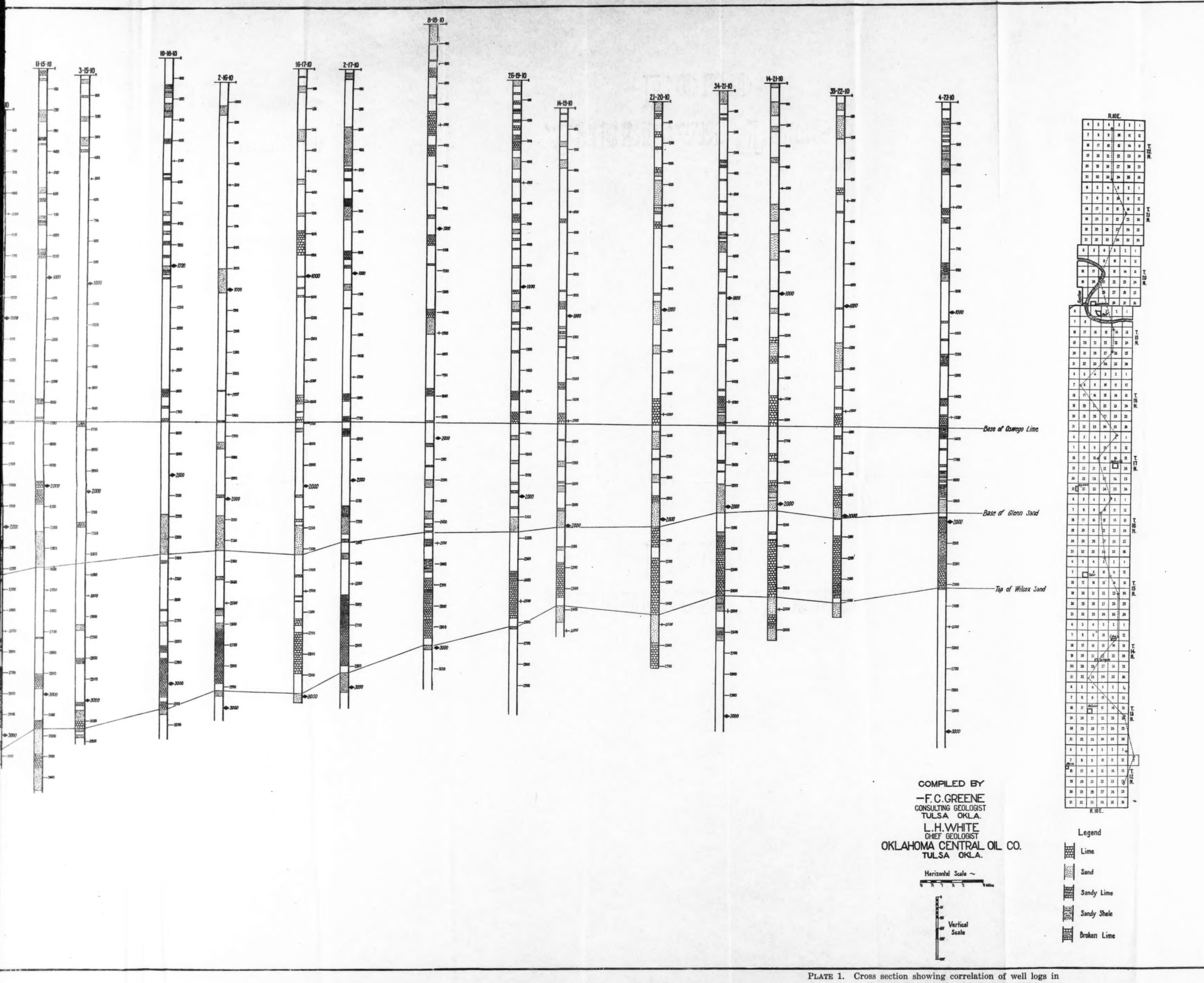

PLATE 1. Cross section showing correlation of well logs in north-south direction through R. 10 E., Oklahoma.

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culty in correlating it. Where the "Big" lime is well defined, a shale bed 75 to 150 feet thick separates it from the upper "Oswego." In T. 19 to 22 N., R. 9 to 11 E., limestones 10 to 30 feet thick are logged from 10 to 150 feet above the "Oswego." In places there appears to be a progressive thinning of this interval to the west, in others, it thickens and thins haphazardly. The conclusion is therefore drawn that some of these limestones are at the horizon of the "Big" lime and that others are lenses in the Labette shale. South of T. 18 N., the correlation of the "Big" lime is even more difficult. It is logged as a thin "lime shell," as sandstone, or is not reported at all. A thin limestone resting on a thick sandstone in T. 11 N., R. 11 E., is probably at the horizon of the "Big" lime. This is near the middle of the Wewoka formation, about 610 feet below the Checkerboard and 550 feet above the Calvin sandstone. It should be noted that in many logs in the Glenn pool and vicinity the upper "Oswego" is logged as "Big" lime.

"Oswego" Lime—In Osage county the term "Oswego" is usually applied only to the upper of the two limestones which form the Fort Scott limestone. The interval between the two, which is about 20 to 40 feet at the Kansas line, gradually thickens to about 150 feet in T. 15 N., and in places contains an oil sand. The upper "Oswego" has an average thickness of 40 to 60 feet, but becomes irregular south of T. 17 N. The lower member is usually 10 to 20 feet thick.

In the Glenn pool district the upper "Oswego" is a rather uniform bed and an excellent marker. It is usually logged as "Big" lime. The lower "Oswego" here about 100 feet lower, is logged as "Oswego" lime. It is believed that the upper member becomes irregular at a point farther north than the lower member and that the latter is the bed usually logged in the Beggs region, but where the two beds are of nearly the same thickness, and where other thin limestones are also present, the correlation of either member of the "Oswego" is uncertain, as may be seen on the cross-sections.

The lower "Oswego" is in places reported as capping a coal bed, and below this there are one or more lenticular limestones. In some logs the lower "Oswego" and the underlying

limestones are reported without breaks, as a limestone 30 to 50 feet thick.

Interval between "Oswego" and Bartlesville—Generalizations concerning the interval between the "Oswego" lime and the important groups of sandstones below must be considered only tentative. Information is to be obtained chiefly from well logs, as neither of the writers has made a study of the outcrops over any considerable area. In the upper part of this interval there is locally a sandstone, as T. 16 N., R. 12 E., having a maximum thickness of 150 feet. This is the Prue[1] or Perryman sand and is probably the equivalent of the Calvin sandstone of the Coalgate quadrangle. The interval between the lower "Oswego" and the top of this sand is extremely variable—from almost nothing to 150 feet, and as already mentioned the sandstone itself is lenticular.

In the northern part of the area under discussion, that is T. 19 N., and northward there is a thin limestone at a distance of 250 to 300 feet below the upper "Oswego" which is called by drillers the "Pink" lime. This limestone is a few to 100 feet above the Bartlesville sand in Osage county and is probably the limestone that bears a like relation to the Red Fork sand in T. 19 N., R. 10 E., but the writers are not prepared to state this positively.

In the southern part of the area a very important key bed is the Henryetta coal. Its extent is not known but it has been reported in wells from its outcrop to T. 10 N., R. 11 E., and T. 13 N., R. 10 E. It lies 260 to 450 feet below the top of the Calvin sandstone and 600 to 780 feet above the top of the "Glenn" sand. This is approximately the position of the "Pink" lime and the Bartlesville sand.

Bartlesville, "Glenn," and Red Fork sands—In the cross sections an attempt has been made to correlate the base of the "Glenn" sand. It will be noted that this horizon is shown to be equivalent to the base of the Bartlesville. In making this correlation, it is realized that more study is needed before this point can be definitely settled. It has already been mentioned that the evidence in hand seeems to indicate that the

[1]The name Prue is probably also applied to the sand between the upper and lower "Oswego" limestone.

top of the Red Fork is the equivalent of the top of the Bartlesville. If such is the case the thin shale break locally reported in the Bartlesville sand increases to about 200 feet in the distance covered by these cross sections.

The top of the Bartlesville sand lies about 325 feet below the base of the upper "Oswego" lime in Ts. 21 and 22 N. In T. 18 N., this has increased nearly 200 feet. In T. 15 N., the top of the Red Fork sand is 450 to 500 feet below the lower "Oswego." The increase south of this township is very rapid, but as the Red Fork can not be certainly identified in T. 11 N., figures can not be given. However, the top of the "Glenn" is 1,200 to 1,300 feet below the top of the Calvin sandstone in that latitude. This interval increases rapidly in T. 11 N.

The Glenn sand can be identified certainly as far north as T. 20 N., R. 10 E. It increases southward to about T. 14 N., where it reaches a thickness of as much as 175 feet. It decreases to the south and in T. 11 N., it is rather thin. In the latitude of Tulsa it shows a marked thinning to the east and it is difficult to identify it in the eastern parts of Ts. 18-19 N., R. 12 E. One of the distinguishing marks of the "Glenn" sand is a thin limestone lying from 30 to 40 feet below it. The base of the "Glenn" sand or "Salt" sand as it is often termed, is the most important marker in the Pennsylvanian of the Okmulgee district. It usually contains water and the base is often measured with a steel line. It may be the equivalent of the Thurman sandstone of the Coalgate quadrangle. If the writers are correct in the correlation indicated on the cross-section the interval between the "Glenn" and Red Fork sand is a negligible quantity to the north, but continually increases to the south and in the vicinity of Beggs will average about 200 feet.

The interval from the base of the "Glenn" to the top of the "Wilcox" increases both southward and eastward. In T. 22 N., R. 10 E., it is 355 feet and in T. 12 N., R. 11 E., it is 1,475 feet. In R. 12 E., the increase is from 385 to 1750 feet. The averages are 18 feet per mile and 25 feet per mile respectively. In R. 12 E., the increase is less than the average north of T. 16 N., and greater than the average south of T. 16 N.

Booch or Taneha sand—From the Arkansas river southward the Booch or Taneha sand is found in most of the holes drilled through its horizon. It is extremely persistent, but it is also extremely irregular in thickness, varying in thickness within a few miles from 10 to over 250 feet. Where it reaches this great thickness, it is often confused with the "Salt" sand by the drillers.

The top of the Booch or Taneha sand probably averages about 200 feet below the base of the "Glenn" and the bottom is about the same distance above the Dutcher. In common with other intervals, they average slightly less to the north and slightly more to the south. A peculiar feature of this sand is that when it is unusually close to the sand above or below, it will generally be found at a greater distance than usual from the other sand, that is, the interval from the base of the "Glenn" sand to the top of the Dutcher is fairly uniform in any particular locality.

Dutcher sand—The Dutcher sand presents some unusual problems in correlation and stratigraphic relations. It is believed to be the oldest sand in the Pennsylvanian series in this area. In the central part of the area under discussion, it is a fairly well defined sand. It is commonly overlain by limestone, which in places is of considerable thickness, and in other places it appears to grade laterally into limestone. As it lies unconformably on the Pitkin or Boone, there may be isolated occurrences of the Dutcher sand far to the north of the main body. In such cases it would, of course, be hard to prove their equivalence.

Southward from the central part of the area, the Dutcher sand thickens and contains shale partings. The partings thicken to the south and in T. 13 N., there are two or more sands and the basal member is separated by more or less shale from the top of the underlying Pitkin or Boone. The Dutcher sand is probably the equivalent of the Squaw, Rhodes, Scott, Burgess, Youngstown and Deaner sands.

Mississippian—In the northern part of the area, the Mississippian is logged as a solid body of limestone about 300 feet thick. In the upper part there appears to be a local sand lense, "the first break in the lime," or Burgess sand. This may

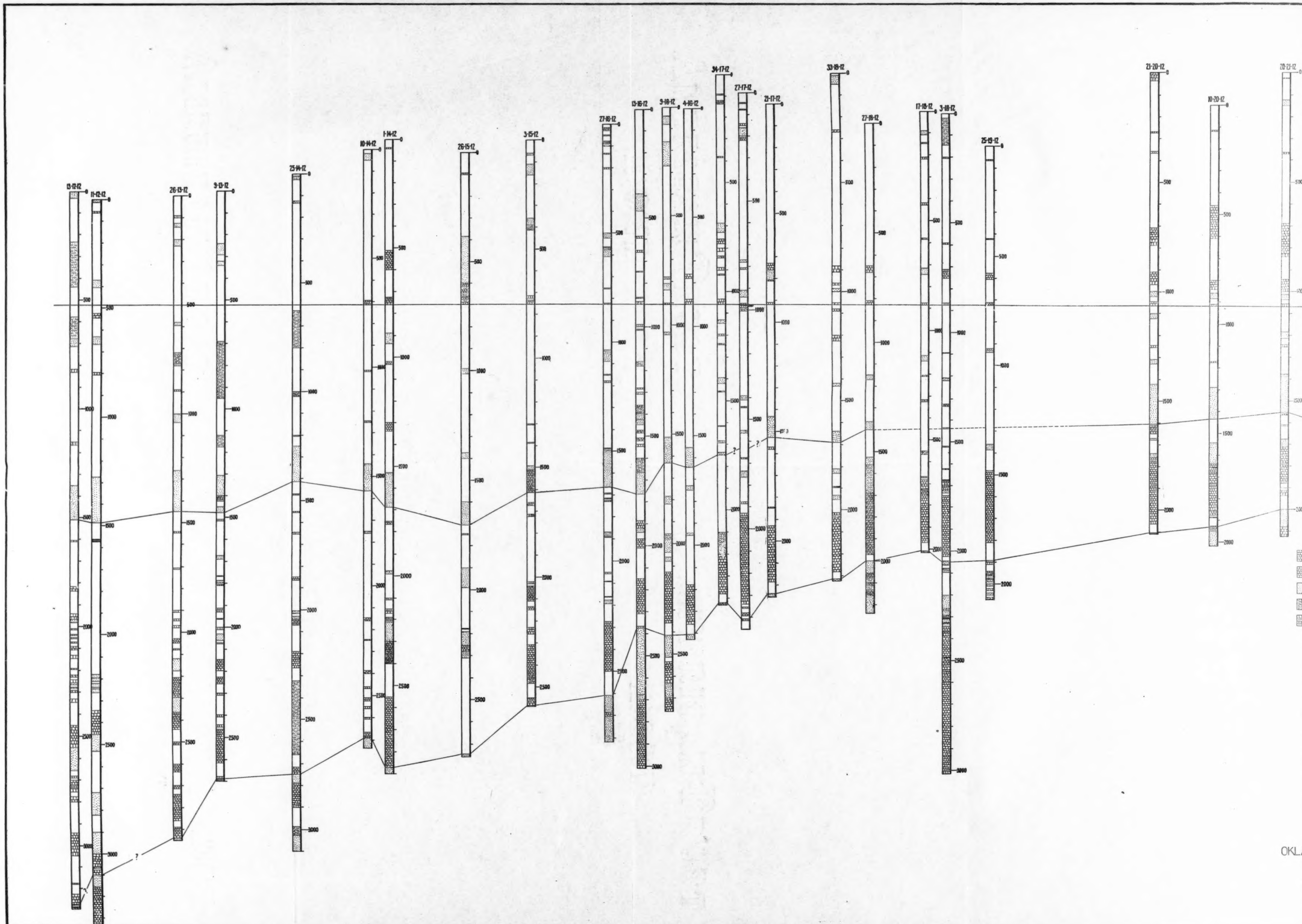

PLATE 2. Cross sect
north-sout

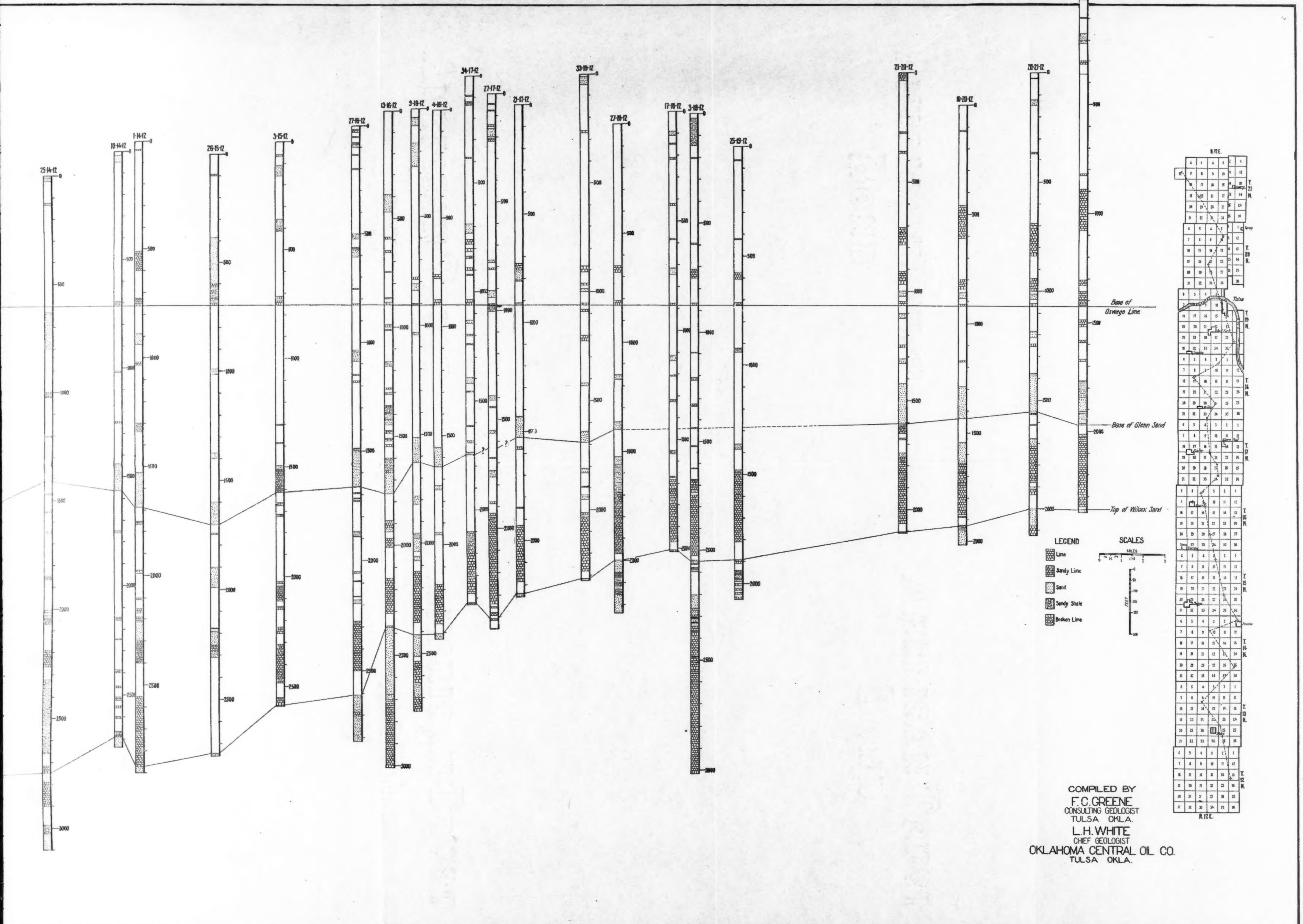

PLATE 2. Cross section showing correlation of well logs in north-south direction through R. 12 E., Oklahoma.

be correlated with the Dutcher sand, as suggested above. In general there is a gradual change from top to bottom of light gray to dark gray or black lime, and occasionally a log shows thin breaks of black shale toward the base.

Southward there is a thickening of the Mississippian and in T. 14 and 15 N., a persistent but irregular black shale is present between the two limestones. In T. 14 N., R. 11 E., the upper limestone is about 100 feet thick, the shale 165 feet and the lower limestone 175 feet. The limestones are usually reported to be black. A possible correlation is Pitkin, Fayetteville and Boone respectively. Farther south this group of limestones increases in thickness but the individual limestones split and thin and the amount of shale increases. The limestones also become argillaceous. In T. 13 N., R. 12 E., and probably in other places a sandstone is present in what is considered possibly the Fayetteville. In T. 12 N., R. 12 E., some parts of the limestones are recorded by drillers as "cinnamon" which is interpreted to mean a soft, brown, argillaceous limestone.

"Wilcox" sand—In the zone of sands lying below the Boone there are three and possibly more sands to which the name "Wilcox" has been applied. In addition to "Wilcox," the following names have been used for these sands: Mounds, Black & Simons, Mose Carr, Irish, Marland, Misener, 300-foot break (in the Osage), and Wiggam (in southern Kansas.) The main characteristic of this zone is the presence of an overlying bed of black or green shale, a few to 100 feet thick, which in turn is overlaid by a thick body of limestone, the Boone.

It is believed that one sand in this zone is fairly persistent, but if this is true it calls for some rather remarkable depositional conditions. On the assumption that this persistent sand is the Sylamore, a floor of nearly perfect peneplanation must be postulated. Thin limestones of the Pennsylvanian are even more persistent than the "Wilcox" sand - but they are, of course, conformable, whereas the Sylamore sandstone is separated by an angular unconformity from the underlying beds. However the persistence of the "Wilcox" sand in closely drilled areas and its presence in many widely separated wildcats is considered good evidence that it is persistent.

Another condition that is required if it be assumed that one sand in this zone is persistent is the presence of a rather uniform limestone above the sand and below the black shale. This limestone is in nearly all logs reported as hard and white and from a mere shell to 70 feet thick. Its lithology is somewhat variable. The upper part is nearly pure crystalline limestone. Below the middle it becomes sandy in some places, but remains calcareous in others. In places it contains thin streaks of sand in the lower half. In many cases the line of demarkation is drawn where the bed becomes porous enough to contain oil, gas, or water rather than on strictly lithologic grounds. In general the limestone becomes more persistent to the south and more irregular to the north. It is not reported to be present where the Sylamore sandstone and the overlying Chattanooga shale appear in the outcrop.

In a few places a sand has been found above the true "Wilcox" sand. A typical example of this is the Misener sand in the east central part of T. 15 N., R. 10 E. This sand is overlain directly by black shale and in places is underlain by the same material, but locally it appears to rest directly on the white limestone above the true "Wilcox" sand. The average interval between the Misener and "Wilcox" sands is about 75 feet.

The third producing sand below the Chattanooga is believed to be below the true "Wilcox" sand. Whether these sands are near "Wilcox" age or whether they belong with the underlying Ordovician (Tyner or Burgen formation) is difficult to determine. It is possible that in local depressions in the Ordovician surface lenticular sands, shales and limestones levelled up the surface to that of the true "Wilcox" which in all cases is present, so far as known. The name "Irish" sand doubtless owes its origin to the green colored shales with which it is associated.

Strata below "Wilcox" sand—In the Tahlequah quadrangle the Sylamore sandstone rests with unconformity upon the St. Clair marble of Silurian age and likewise upon the Tyner formation of Ordovician age. As the St. Clair marble is at least 200 feet thick, the unconformity is an angular one and in

other places still other formations may be present below the contact of Sylamore.

The material reported below the "Wilcox" sand in probably a majority of the holes consists of thin alternating strata of sandstone, limestone and shale of several different colors, notably green and red, a "barber pole" succession. This is probably the Tyner formation, though some of this material may be post-Ordovician. In other wells thick bodies of "sand," "lime" or "sandy lime" are reported, either because the rocks are present or through error in determining their lithology. It should be recognized that Ordovician and Silurian rocks are almost unknown to the average driller, and are not likely to be logged as correctly as the higher beds. For example, a crystalline limestone or dolomite is often logged as sand or sandy limestone. The only method for correctly determining these strata is from a study of cuttings.

Both oil and gas have been found below the "Wilcox" sand, in some instances over 100 feet below, as for example the wells in sec. 5, T. 19 N., R. 11 E., which got oil, and the wells near Inola which obtained gas. As already mentioned some of these beds may be of an age near the "Wilcox." Toward the north line of the state the beds immediately below the horizon of the "Wilcox" sand are limestone or dolomite in all logs that have been studied.

CONCLUSION

The writers recognize the difficulty of tracing formations over long distances, by means of well logs, but they believe they have made a strong case for the equivalence of the "Wilcox" sand and the "300 foot break in the lime." The general continuity of the individual beds and the general thickening of the shales and sandstones to the south have been discussed in some detail to show why the "Wilcox" sand lies at a greater depth to the south than to the north where wells start in a higher stratigraphic horizon. Cuttings from numerous wells in Osage county have shown beyond question the pre-Boone age of the "Wilcox" sand there.

DISCUSSION

ON "THE RELATIVE AGES OF MAJOR AND MINOR FOLDING AND OIL ACCUMULATION IN WYOMING," BY MAX W. BALL

The evidence of a theoretical nature presented by Mr. Ball[1] to demonstrate that the major and minor folds in Wyoming are of at least approximately the same age is a valuable contribution to the writings dealing with Wyoming structural conditions. His work which demonstrates that the great folds represented by some of the mountain uplifts were at least affected by, if not inaugurated by, stresses that acted as recently as Eocene time, and that many, if not all, of the minor anticlines are equally as old, will be utilized time and again by students of structural conditions. However another line of evidence even more conclusive, can be called upon to show the fallacy of the idea that "the greater part of the oil originally in the shales migrated **** to the crests of the major folds, from which erosion has since removed it." Regardless of what theory may indicate, it must in the end conform to the facts that are actually observed, and the observed facts demonstrate that the generation, migration, and accumulation of oil is not a rapid process which may be accomplished and terminated in a comparatively short time, or even in the period needed to permit the formation, consolidation, contortion, and partial removal by erosion of the upper Cretaceous of Wyoming. The oil in the beds of White River age in the Douglas district may be cited in support of this. The impossibility of this oil originating in the Tertiary formations is evident. Yet the White River formation is separated from the oil yielding Cretaceous by profound unconformities, and was deposited after folding had practically ceased. In Oklahoma the little field near Madill in Marshall county is another case in point. In this field the oil occurs in Cretaceous rocks, but it must have been formed in beds of Pennsylvanian or pre-Pennsylvanian age, from which it did not escape during all of Permian, Triassic, and Jurassic time. The accumulation of oil along planes of unconformity in some fields, and its migration along similar planes in other fields have long been recognized as factors that must be considered when studying the oil yielding possibilities of a region, and prove absolutely that strongly stressed and deeply eroded formations may still retain enough oil to form pools capable of yielding hundreds of millions of barrels.

Mr. Ball's mention of the greater productivity of basinward anticlines in Wyoming gives an opportunity to present a theory which may explain this greater productivity,—an explanation that is independent of the relative ages of formation of the anticlines and which differs very markedly from the explanation of mountainward migration of the oil advocated by Hewett and Lupton[2]. Their work in the Big Horn Basin and

[1]Bull. Am. Assn. Petrol. Geol., Vol. 5, No. 1, pp. 49-63, 1921.
[2]Hewett, D. F., and Lupton, C. E., Anticlines of the Big Horn Basin: U. S. Geol. Survey Bull. 656, pp. 43-47.

in other parts of Wyoming indicated that where there were two or more anticlines paralleling the rim of a great structural basin, such as Big Horn basin, the mountainward anticline was commonly barren, whereas the basinward anticline not uncommonly yielded oil or gas or both. At the time the hypothesis was advanced there was practically no exception to the nonproductivity of the mountainward anticline, although there were several basinward anticlines which had not been proved to contain oil. The theory in brief is that oil and gas disseminated through the great expanse of beds in the basin, migrated slowly up the dip, and accumulated in the first structural trap encountered. This would be the basinward anticline and, provided this anticline had storage space enough, it seemed evident that little oil would be able to progress beyond it to be accumulated in the mountainward fold.

Since the above hypothesis was framed drilling in some of the mountainward anticlines has revealed the presence of large pools of oil in horizons deeper than any which had been prospected at the time Hewett and Lupton did their work. There has also been found at least one instance—Kirby Creek—of an anticline which was not a basinward anticline containing some oil and gas in the shallower sands of the Frontier formation, even though an anticline parallel to it and farther out toward the basin has not been shown to contain any appreciable oil pool, and it is probable that unmapped anticlines exist on the basinward sides of some of the productive folds.

One of the most significant factors which must be taken into account when formulating any hypothesis to account for the barrenness of some of the anticlines and the productivity of others is the presence of fresh water in the sands of the Frontier formation that carry oil in many of the basinward anticlines. These Frontier sands are marine in origin and therefore contained salt water at the time of their deposition. Fresh water in these sands must have gotten there since the uplift of the region as a whole, and shows they are or were connected with actively circulating ground water, surface water, or both. As a result both the salt water and any oil which may have been in these sands in the mountainward anticlines has been washed out by fresh water encroaching from the exposed edges of the formations. It would follow that the farther an anticline is from a water intake of the oil-bearing sand, the greater would be its likelihood of containing oil. Accordingly, it appears that the prospects of an anticline containing a commercial oil pool are directly proportional to the distance of that anticline from a water intake of the oil-bearing sand and also depend upon factors which will affect encroachment, such as faults, variations in porosity, continuity of beds, and hydrostatic head. In this connection it must be recognized that not every outcrop is so situated that it will admit a great volume of water.

Inasmuch as the outcrops of progressively deeper horizons normally are progressively more remote from an anticline, it is easy to understand why the upper oil measures in an anticline might yield nothing but fresh

water and lower beds contain large volumes of oil. In the case of the oil in the Embar and Chugwater formations the character of the oil has undoubtedly added to its stability. The oil in these formations is commonly of low Baumé gravity and has comparatively high viscosity, and it should therefore resist any displacing action of encroaching water with more success than could the lighter oils of the Cretaceous formations.

K. C. Heald.

EDITORIALS

ESTIMATES OF PETROLEUM RESERVES

The United States Geological Survey proposed to the Association at the last annual meeting a co-operative plan whereby the petroleum reserves of the United States could be re-estimated during 1921, and the results published on or about January 1st, 1922. The plan was adopted by the Association and, as has been stated elsewhere in Bulletin 2, a committee for this purpose was appointed. It is the plan of the Association to estimate the reserves of the Mid-Continent field, Kansas, Oklahoma, Texas, and Louisiana, and to co-operate in estimating reserves in other states. Each member of the original committee has formed a sub-committee to divide the work by districts and these sub-committees will hold meetings during this year, these meetings to be followed by a general meeting of the main committee. In selecting memberships of the committee and sub-committee the aim has been to include all those who would be willing to assist in this work. Any others who could furnish information which would be of assistance should communicate with a member of the main committee. It is thought by a number of workers that a careful review of the past production of the Mid-Continent field and a revised estimate of future reserves will be more optimistic than past estimates have been. The possibility of new inventions which will obviate the use of oil and its products as fuel is to be seriously taken into account. Also the possibility of extraction of a much greater per cent of unmined oil in the ground by improved methods of recovery is an equally important factor in estimating future reserves. It is believed that by due consideration of these and other factors a prediction of future production for each state can be made and this estimate published in the Bulletin after the publication of the U. S. Geological Survey report. The Association can render to the oil industry a timely and mature report which will be of great value to all engaged in this industry.

In the Oil and Gas Journal for November 28th, 1919, David White estimated the available oil reserves in the ground in January, 1919, for the United States as follows in barrels:

California	2,250,000,000
Oklahoma-Kansas	1,725,000,000
Gulf Coast	750,000,000
Appalachian	550,000,000
North Texas	400,000,000
Wyoming	400,000,000
Alaska, Colorado, Michigan, Montana and other States	350,000,000
Illinois	175,000,000
North Louisiana	100,000,000
Lima-Indiana	40,000,000
TOTAL	6,740,000,000

S. P.

PESSIMISM IN GEOLOGY

Geologists are pessimists. The primary function of petroleum geology is to find structures that are favorable for oil accumulation and to secure tests of them. Incidental to this work, many proffered leases are condemned as not worth a test and many reported structures are examined. But the success of petroleum geology depends upon constructive work.

Geologic knowledge of petroliferous regions is dependent on field work, usually preceded by study of available literature and by consultation with geologists who have already examined the regions. The opinions expressed in print and by other geologists have great bearing on the conclusions reached. The literature rarely describes the formations in an undeveloped country in such a manner as to indicate suitable petroleum reservoirs or sources for petroleum. Furthermore, it dwells on time honored theories, such as the one that "the 'Red-beds' are unfavorable for oil accumulation," although many of these theories have been or are being abandoned by the active workers in the profession. Therefore, the first source of information is, in general, pessimistic.

Other geologists—the second source of information—combine the literature with field evidence and offer a conclusion. But frequently no one can be found who is familiar with a particular region. When other geologists are available the accordance of opinion is usually that if the region is undeveloped (even locally) it is comparatively worthless because "geologists have examined it during the past ten years and have not recommended it."

With all the discouragement offered, the geologist ventures forth, finds structure, which elsewhere would be considered favorable for oil accumulation, but finds "Red beds" or limestone of "unknown thickness" or finds no sand or too much sand in the section. The report is unfavorable. The geologist feels that he must be conservative and that each dry hole adds discredit to his work whether or not his interpretation of the structural conditions is correct. Next, the operator decides to test the structure irrespective of the unfavorable report and completes an oil well in a region "condemned by geologists."

Do we not need a bit more optimism in our profession so that we will be willing to locate wells far from production either on local structure or on broad interpretation of regional structure? Should we not encourage the drilling of wells in undeveloped territory, base our locations on sound scientific reasoning and defend our locations even though the tests are dry?

S. P.

PROGRESS IN PETROLEUM GEOLOGY

It has now been just about eight years since the big wells at Cushing ushered in the phenomenal growth of the petroleum industry in the Mid-Continent, put the anticlinal theory on a sounder basis, and created a demand for geologists not dreamed of in the earlier years. During this interim the petroleum industry has had a most remarkable growth, and geologists have played a leading and a very creditable part in this great enterprise. Yet in some respects it appears that petroleum geology as a science has made very little progress as compared with some of the allied sciences, such as industrial chemistry, electrical engineering, aeronautics, and others.

In 1911 the petroleum classics by I. C. White, A. Beebe Thompson, Boverton Redwood, Ralph Arnold, and M. J. Munn had already been published. Since that date what has been added? Through the work of McCoy, Schuchert, and Woodruff the relationships between oil-field provinces and shorelines has been pointed out, and we have been enabled to discriminate more clearly between the favorable and unfavorable territory. Another clue has been added by David White and Myron Fuller who have given us the relationships between the amount of fixed carbon in coal and the usual occurrence of oil and gas. Through the excellent work of Beal and Ralph Arnold the application of decline curves to valuation methods has been so worked out as to eliminate a large degree of uncertainty and to open up a new line of work for many geologists. Through the writings of Mrazec, van der Gracht, Deussen, and others our knowledge of the true structure and origin of the coastal salt domes, has been increased yet much on this subject remains to be published. Experiments by E. A. Starke, Rogers, and Nolan have enabled us in many places to determine the source of water in deep holes by methods of water analysis, many minor improvements of old methods have been made, and much new information about local areas has been added to our general information. Yet we can count on a few fingers all the important new discoveries that have marked a distinct advance in our science.

On the other hand it is unnecessary to point out that in the same ten-year period industrial chemists have revolutionized the dye industry in this country, have made glass which will stand sudden changes in temperature permitting great improvements of household utensils and laboratory apparatus, have invented numerous new explosives enabling projectiles to be thrown distances of as much as 75 miles, have invented ways of making nitrates out of the air, helium out of natural gas, and alcohol out of petroleum. Our friends, the electrical engineers, have put electrical contrivances into our homes, so that our wives can wash, iron, cook, and sweep with electricity, and have also developed the marvelous wireless telephone. The aeronautical engineers have crossed the ocean in their airships. Notable advances have been made by our topographers in the use of photography in map making. Is it not evident that Petroleum Geology has not made so noteworthy a showing?

It is intended, therefore, to point out briefly some of the reasons for this lack of advancement in our science, to call attention to the need of a greater endeavor among American geologists in the future, and to suggest schemes to help our progress.

One of the chief reasons for the lack of greater progress toward new discoveries, it seems to the writer, is that American geologists do not have time to think or to study as do our friends in other lines of research. The chemist has his laboratory and his library, he has at hand on his desk the published results of all his colleagues, and from the start he makes use of all the known information. Then he is able to concentrate for a long period over a large amount of material at his disposal, if needed, until he solves his problem. The geologist runs from one field to another, and often all the library he ever sees is his pocket notebook. He writes his report on the Pullman and is obliged to spend more time thinking about advising his board of directors how to run their corporation than to working the problems of determining more certainly whether oil exists beneath a certain anticline, how to locate domes in an alluvium-covered region, or how the greatest possible amount of oil can be recovered from a given amount of oil sand. Again, when by chance the geologist does steal the opportunity to work on a pet scientific problem, he hardly ever has at hand the results of his fellow workers, so that without knowing it many geologists work on problems which have already been solved by others. Most important results do not remain trade secrets long, and the information is available if only the geologists know where to go for it or, most of all, has the time to run it down.

Further, during the past period of rapid growth, of keen competition, and of financing the great oil enterprises, haste has been a necessity, and business brains have been more in demand than science. During the next ten years, however, there certainly will be a change. The favorable anticlines of our own country have nearly all been located and leased. The companies are well organized, and unfortunately many of the directors are still young. New concerns that start up will find "harder pickings." There will probably be less demand for geologists to manage business affairs, and to a greater extent will geologists, who wish exploration work, be obliged to go to foreign fields. On the other hand our own oil reserves are getting smaller each year and the demands for fuel and gas greater. There will be an urgent demand for greater conservation, greater efficiency, greater recovery and *more science*. The U. S. Bureau of Mines is doing some excellent work at the present time, but the Bureau can not do everything unaided. Unless petroleum geologists rise to this second call with the same ardor with which they met the business demands, the profession will suffer and there will be more complaints that times are dull and it is hard to find good jobs. The period is already past when a sophomore from college, armed with the knowledge of a few technical words and a wise look, can go out and earn his $75 per day looking for anticlines. In the future a petroleum geologist must study more, must

think more, and above all should know what his colleagues have already done and he must be able to profit by their experiences and contributions. Each worker should as far as possible begin where the others left off. Certainly Gulf Coast geologists should not work on problems already solved and published by Roumanian geologists because the Roumanian work was published in a Roumanian report and in French. The Roumanian geologists do not hesitate to get hold of all our U. S. Geological Survey publications on oil and to read them too.

But how then can these ideals be best furthered and our science developed? The present American geological organizations are perhaps the greatest potential means of helping and encouraging progress. The American Association of Petroleum Geologists, the American Institute of Mining Engineers, the Southwestern Association of Geologists, the American Petroleum Institute, the U. S. Geological Survey, and the U. S. Bureau of Mines—all these organizations and others, but particularly the first offer opportunity for the interchange of views, furnish a means of publishing results when permitted, and bring out new ideas and new inspirations. These organizations should be supported by every petroleum geologist, by the oil companies, and by all others who are interested in progress. Our petroleum society is still young, yet has fully demonstrated its worth by its wonderful growth and the fine support it has received. Yet there is much more that can be accomplished. The publication of the proceedings monthly or semi-monthly instead of yearly will be a step forward as a means of furnishing more quickly and regularly the new papers and discussions. There is no reason either why the meetings should not be held oftener than once a year—why not quarterly or twice a year? Also the writer would propose the establishment of a library bureau for the distribution of geological information and general oil news, especially of foreign affairs which are not readily accessible to the average geologist. Such a scheme would make up for the lack of libraries, for scientific journals, and would enable members to learn more quickly of new ideas, and make it possible to procure easily and quickly a list of all the essential articles published on a given subject or foreign country in which he is interested. Already the American Institute of Mining Engineers has worked out a plan to help its members in mining camps to get literature, but the service is rarely made use of by petroleum geologists. The Geological Society of England has a library service by which books are sent out to all members requesting, on a two weeks loan, with the privilege of the renewal of the loan in case the books are not called for by another member. It may be of interest to note that it is not the books on English subjects which are most requested, but information on foreign lands. Thus our British cousins keep themselves informed on what is going on in all parts of the world. Most American geologists, on the other hand, read little outside their own local interests. The successful establishment of such an information bureau requires careful study and much work by an able committee backed by the whole-

hearted support of the entire organization. Therefore, if this is of interest to the society, it should be fully discussed.

One final point might be mentioned. Our friends, the chemists and electrical engineers are encouraged to greater effort through the direct monetary returns that they might derive from a successful patent. It is not so easy to see ahead a direct reward for a geologist who successfully copes with a difficult water problem in the face of ridicule by the drilling staff. Therefore, you who are at the heads of your departments and in close touch with the directors should see that promising resident geologists have the opportunity, and encouragement to work on the large problems which confront the oil field operators, and when they are successful those in authority should see to it that a commensurate reward is forthcoming either in the form of a bonus or promotion to encourage further effort. In this line also it is a suggestion that the Association might find some way of giving special recognition to a notably good or new contribution received as a paper for publication. After all, geologists are all human, and it is only angels who strive to progress when there is no reward.

F. B. PLUMMER.

GEOLOGICAL NOTES

CRUDE OILS OF BORNEO

At a meeting of the Institute of Petroleum Technologists of England held in London on March 15th, 1921, Mr. James Kewley, F.C.S., F. I. C., a member of the Royal Dutch Shell group, read a paper on "The Crude Oils of Borneo." This paper gives a brief history of the development of the petroleum industry in the Dutch East Indies, reviews the geology and structure of the oil fields, describes in some detail the chemical characteristics of the oil and the different by-products obtained from the crude, and concludes with an interesting discussion of the possible relationships of the chemical composition of the oil to its mode of origin. Altogether the paper is an excellent contribution on a most important oil region concerning which very little has been published heretofore.

One of the most interesting districts described is that of Koetei in eastern Borneo. The strata here are of Pliocene and Miocene age. The Miocene rocks in which most of the oil occurs consist of interbedded clays and sands containing numerous lenticular coal beds. The whole formation is thought to have been laid down under delta conditions. Below this upper formation occurs greensand, glauconitic marls, and foraminiferal limestones and marl beds of early Miocene and Eocene age. The author concludes that the oil originated in the lower Miocene and Eocene marls and limestones and migrated upwards thus saturating the delta deposits. The oil accumulated along the well-defined anticline known as the Sanga Sanga fold, which is situated near Balik-Pappan, and is divided into two domes. The northern dome supports the Sanga Sanga-Miri oil field and the Sombodja oil field. The author finds that the deeper oils, those occurring in the deeper portion of the formation below the coal beds, are rich in paraffin wax. The oils found at high levels in or above the coal beds are poorer in paraffin and richer in aromatic and asphaltic constituents.

A consideration of these observations has led the author to suppose that the adjacent coal has had some chemical effect on the oil. He states that the oil in its upward migration has come in contact with or passed through the coal beds, and chemical reactions have taken place between the oil and coal in such a way as to result in a diminution of the wax content and an increase in the aromatic and asphaltic constituents. In further support of this idea, Mr. Kewley points out that in the Miri fields where coal is absent the oil is also low in aromatic and asphaltic content from whatever depth it is obtained, and that the oil at Perlak in Sumatra where coal is also absent is lower in the aromatic and asphaltic constituents than the oils of Moera Enim, Sumatra, where coal seams are known.

Note: It would be interesting to know if members of the Association of the Petroleum Geologists in America have observed any similar re-

lationships in any of the American fields where coals or lignites occur near the oil sands.

The following officers were elected by the institution to serve during the following year:

President:
Prof. John Samuel Strafford Brome.

Vice Presidents:
Herbert Barringer
Sir George Bailly
Sir John Cargill
Arthur E. Eastlake
Viscount Cowdray
Sir Thomas Holland.

F. B. Plummer.

ANOTHER DEEP TEST IN PENNSYLVANIA

The Peoples' Natural Gas Company encouraged by the success of its very deep well on Chestnut ridge east of Ligonier, which is thought to be producing from the Oriskany at about 6,822 feet, has started a second hole. The first well went only a few feet into the sand and was obstructed by a fishing job so that the yield is not great—about one-half million cubic feet. However, the pressure and persistence has been such as to encourage them to drill a second well.

As is apropriate for such expensive wells the spacing is good, apparently about one-half mile. The second well lies to the west of the axis, the first one having been located to the east of the axis.

I. C. White.

THE RECENT DISCOVERY IN ARCHER COUNTY, TEXAS

The most interesting and important development in the Wichita Falls, Texas district, has been the discovery of the new Gose pool in northern Archer county, Texas, about six miles southwest of Holliday. The Texhoma Oil & Refining Company brought in their No. 1, S. M. Gose, about March 12th, and since that time the well has averaged over 150 barrels daily from a good sand at 1,599-1,604 feet. Several wells have been drilled since, among them the Texhoma Company's No. 1 Taylor, about 1,000 feet north of the discovery well which has found production in an upper sand at 1,317-21 feet. This well was estimated at 50 barrels or better and it shows the presence of two producing horizons in the field. The J. I. Staley No. 1 Coffman about a quarter of a mile to the southwest of the discovery well has encountered the lower pay at about 1,608 feet and has proved to be the best well brought in to date. It was reported to have an initial production of over 500 barrels. As yet however, there is very little proven territory.

By using data from a number of deep wells drilled in the county, it might be possible to work out the structural relationship of the sands

with the heavy lime series found in the northern part of the county at depths varying from 1,750 to 2,200 feet and in general work out the regional structural conditions.

On the surface is found a series of sandy red clays and shales with an occasional bed of greyish white sandstone which becomes slightly calcareous to the south. All are of the Wichita-Albany formation of the Permian and an estimate of the thickness would be between 1,500-1,700 feet. It is uncertain as yet whether the oil is in the lower Permian or in the Pennsylvanian.

Dallas, Texas, May 18, 1921. L. B. Benton.

THE NEWCOMER SOCIETY

This new scientific society has been formed in London for the study of the history of engineering and technology. The prospectus emphasizes the fact that engineers have served the world as well, if not better, than generals and politicians, yet their works are almost forgotten, and their names remembered by but a few. The history of engineering technology has been, and is being, neglected, and the ambition of this society will be to assist in supplying this deficiency. A journal is promised, as well as a card index of published information. Anyone interested can join, the annual dues being one pound sterling. Headquarters are at the Science Museum, South Kensington, London, and the secretary is Mr. H. W. Dickinson.

THE MEXIA POOL, MEXIA, TEXAS

The Henry well of the Humphreys-Mexia Oil Company, located three miles southwest of Mexia, Limestone county, Texas, heretofore a small producer at around 3,000 feet, was deepened, and on May 7th, increased its daily production to 2,600 barrels from a deeper pay in the Woodbine sand, reported to have been found at approximately 3,100 feet. Previous to this time the district has failed to excite much enthusiasm among oil producers, but the new well undoubtedly entitles it to serious consideration as an important new source of light-gravity oil in East Texas.

The first deep oil was found at Mexia in the Rogers well of the same company late in November of last year. It flowed at intervals of about 72 hours from a sand at 3,060 feet, making from 100 to 200 barrels at a flow. Since that time six wells have been completed good for from 100 to 300 barrels each. These wells are all within the limits of the old shallow gas field and prove up the deep sand along a strip of territory about four miles long. They are all situated along an almost straight line extending from a point about a mile northwest of Mexia in a south-southwest direction, which is the axis of the anticline as mapped by Matson in Bulletin 629, U. S. G. S. Owing to their location along the axis of the structure, the sand thus far has proved to lie relatively level.

The wells start on the Midway formation. Blue Navarro clay shales

persist downward to the gas sand, found from 700 to 900 feet, which Matson correlates with the Nacatoch sand of northwest Louisiana. The Austin chalk occurs from 2,280 to 2,700 feet, followed by several hundred feet of typical Eagle Ford shale. Strata of sand of varying thickness, interspersed through the shale, begin to appear at around 2,950 feet and persist to the greatest depth yet reached, 3,140 feet in the Kennedy well, at which depth salt water with a temperature of 140 degrees was found. The top of the Woodbine horizon is assumed to be from 650-750 below the top of the Austin chalk. The upper 173 feet of the Woodbine was here reported free from water. The sand in the earlier Mexia wells was generally hard and tight, giving promise of long-lived, moderate sized producers, but apparently none of these wells except perhaps the Kennedy were drilled deep enough to strike the Henry "pay."

Prior to the drilling of these deep wells, it was thought by many geologists that the Woodbine sand would probably not be found in any considerable thickness throughout this area, owing to the fact that along the outcrop, it almost completely disappears south of Waco, giving way to a more limy phase, which condition presumably held good down the dip to the southeast. In the light of present development this presumption appears to have been ill-founded. The Woodbine formation contains an abundance of water-bearing sand around Corsicana, judging from the few available well records, and is reported to have made showings of oil. Throughout a large area in northeast Texas between Corsicana and Shreveport the sand is persistent and is usually a prolific source of unusable, highly mineralized water. It is quite safe to predict that favorable structural areas within the bounds where the Woodbine lies within reach of the drill, will hereafter receive more careful consideration than has been the case prior to the Mexia discovery. With particular reference to the local district it might be mentioned that the shallow gas field extends in a more or less continuous belt for a distance of 16 miles, though seldom as much as a mile in width. The deep wells thus far cover only the northern four miles of this belt. No deep tests have yet been drilled along the southward axis of the gas field, which to date remains untested, though highly promising, for Woodbine oil.

The oil is all apparently of the same grade, paraffine base, very dark brown in color, testing around 36 degrees Beaume. Reports on refining tests indicate a small yield of gasoline for a crude of this light gravity, while the kerosene and naptha yield is correspondingly high, which, if true, suggests kinship with some of the oil in northwest Louisiana found at a corresponding horizon, notably the Crichton crude. The writer has seen several refining tests of the Mexia oil which unfortuately are of such wide variance that at the present moment he is unable to make any definite statement regarding its refinement properties.

The Humphreys Company, upon the recommendation of F. Julius Fohs, absorbed the leases formerly held by the local gas company and at the prsent time controls some 5,000 acres in the vicinity of the develop-

ment. The leases were taken with very little competition from the larger operating companies, none of which held any considerable block of acreage in the immediate area, except perhaps the Texas Company which is reported recently to have taken up a large tract midway between Mexia and Grosbeck.

Dallas, Texas, May 9, 1921. W. E. Wrather.

GRANITE WELLS IN CENTRAL OKLAHOMA

Two interesting deep tests have recently been completed in the central Oklahoma fields which give valuable data on the deeper formations. J. F. Sweeney & Company's No. 1, Leva Husky or Russell, in the southwest of the southeast of sec. 22, T. 19 N., R. 11 E., a couple miles south of Sand Springs, drilled through the Mississippi lime at 2,040 feet and got the top of the "Wilcox" sand series, probably Tyner formation, at 2,095. They had 170 feet of "Wilcox" sand, 70 feet of lime and 15 feet of sand in the last of which they had a showing of oil. This might possibly be in the upper part of the lower Ordovician. They drilled in sand and lime, the lower Ordovician group, to 2,867 feet where they encountered red granite and finished the hole at 3,071 feet.

Cosden Company's No. 17 Barnett in the center of sec. 22, T. 17 N., R. 7 E., in the Cushing pool, went through the Tucker sand from 2,735 feet to about 2,900 feet where a little of the green Tyner, or "Wilcox" sand series was encountered. Samples show this formation to be present though the exact depth could not be determined. The lower Ordovician was found at 3,000 feet and red granite at 3,670 feet.

These two tests are the only ones this far south to reach the granite at this writing, though several wells have drilled through much more of the lower section than either of these wells. Wells in the Okmulgee district have had from 500 to 1,000 feet more of the lower Ordovician than the above mentioned wells without as yet having encountered granite.

Tulsa, Okla., May 15, 1921. Richard Hughes.

BUTLER COUNTY, KANSAS*

One of the most important oil districts in the Mid-Continent field, and the area of largest production in Kansas is in Butler county, in the south-central portion of the state. Bounded on the east by the prominent escarpment of the Flint hills, it comprises a region of open, rolling farm land, interrupted in places by oil fields with thick clusters of derricks.

The strata which appear at the surface in Butler county, belong to the Pennsylvanian and Permian systems. The former is represented by rocks belonging to the upper part of the Wabaunsee formation, which occupy a narrow belt beneath the Flint hills escarpment of the Cot-

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tonwood and Wreford limestones at the extreme eastern border of the county. The Permian strata consist of alternating formations of shale and more or less flinty limestones, the lowermost beds being found to the east and successively higher formations to the west. The outcrops of shale and limestone form rather narrow bands with a general north-south trend.

The structural geology of almost all of Butler county has been examined in considerable detail by oil companies operating in the district. The distribution of oil and gas in the Eldorado, Augusta, and Elbing fields is controlled by upfolds in the rock strata, anticlines and domes. In the Eldorado field there is one principal upfold on which are numerous small domes and minor arches with intervening saddles. The producing areas on this main anticline are in places continuous from one dome or minor anticline to another.

Quantities of gas were known to exist in Butler county before oil was discovered in commercial quantities, in June, 1914, near Augusta. Five wells were completed that year, and by the close of 1915 the number was increased to 22. The following table shows the number of wells drilled in the county, and total initial production, by years.

Wells Drilled and Initial Production in Butler county, Kansas

Year	Oil	Gas	Dry	Total	Initial Production,
1914	5	24		29	
1915	22	34	4	60	
1916	835	35	132	1002	214,598
1917	994	28	147	1169	289,302
1918	1144	37	259	1440	306,713
1919	678	16	137	831	112,804
1920	475	2	103	580	53,347

The important producing areas in Butler county are the Eldorado, Augusta, Elbing, Potwin, Douglas, Fox-Bush, and Blankenship fields. Recent developments have opened smaller, somewhat isolated areas such as the Tague-Weaver, Stone-Cameron, and Rosalia pools.

The Elbing field, situated in T. 23 S., R. 4 E., was discovered in August 1918. Since then about 180 producing wells and 70 dry holes have been completed there, but at present very little drilling is being done in the field. Many wells of large initial production were drilled, one producing as high as 4,400 barrels the first 24 hours. The production is obtained from two horizons, the upper being unimportant. The chief producing horizon varies from 15 to 50 feet in thickness, and is reached at depths ranging from 2,300 to 2,410 feet. The limits of this field are well defined by dry holes.

The Eldorado field, T. 25 and 26 S., R., 4 and 5 E., has produced and still produces more oil than any other field in the state. The initial well was drilled late in 1915 and by the end of the year 9 wells had been completed. In 1916, 600 producing oil wells with an output of 15,000 barrels were completed. The daily output at the beginning of 1917 was 15,600 barrels and by September of the same year it had increased to nearly 100,000 barrels per day. At the close of 1917 pro-

duction had fallen to 84,000 barrels and by the end of 1918 to 57,000 barrels per day. Since then production has been declining until at present it is about 30,000 barrels per day. Oil was first discovered in the shallow sand but the big production comes from a deep horizon known as the Stapleton zone. Many other oil and gas horizons have been opened or developed, and they are shown in the following table.

Oil and Gas Horizons in the ElDorado Field, Kansas.

Group	Depth feet	Production	No. of sands	Thickness, ft.
Shallow	500-700	Oil	2	15-20
Inter-		Gas	5	10. av.
mediate	1600	Oil	1	15-20
	2000	Oil	1	10-
Deep	2100-2700	Oil	1	30-60

The limits of production are well defined and only what is termed "inside drilling" is now going on.

The Augusta Field, in T. 27 and 28 S., R. 4 E., was developed only as a gas field for a number of years. In 1914 oil was found in commercial quantities and by the end of the year four wells had been completed. By the end of 1915, 12 more wells were added, while in 1916 200 producing wells were completed. At present very little drilling is being done. The gas sand is found at depths ranging from 1,090 to 1,140 feet, while the oil is obtained from various horizons, 1,800 to 2,000 feet, and from 2,400 to 2,700 feet. The two most important horizons are at about 2,000 to 2,400 feet, the latter being known as the Varner sand. In contrast to the Eldorado field, the Augusta field has been a steady producing area. At the beginning of 1917 it was producing about 41,000 barrels a day and since then it has been on a very steady decline and for the past two and one half years has averaged about 10,000 barrels per day, hardly ever going over 11,000 or below 9,000 barrels.

The Douglas Field, T. 29 S., R. 3 and 4 E., is another one of the oil fields which has been definitely limited and where only "inside drilling" is being done. Gas wells with initial capacity of one to ten million cubic feet have been drilled in a sand which also produces oil, at a depth of 1800 feet. This bed, known as the Douglas sand, varies in thickness from 10 to 40 feet and was the only producing horizon until the past two years. Oil has also been obtained in sands at the following average depths: 2,230 to 2,330, 2,570 to 2,620, and 3,050 to 3,110 feet The initial capacity of the producing wells in this area was not as large as that of the fields to the north.

The Fox-Bush Field, which lies in T. 29 S., Rs., 5 and 6 E., is active at the present time. Oil was first discovered in the latter part of 1917, but very little drilling was done for over a year. In July, 1920, there were 107 producing wells, 13 dry holes, 27 wells drilling, and 27 locations, and at the end of the year there were 150 producing wells, 20 dry holes, 9 gas wells, and about 20 drilling and about 10 locations. The sand, which is found at a depth varying from 2,750 to 2,850 feet, and is

known as the Fox-Bush sand, lies directly above the Missisippi limestone. It is very low in porosity and rather light in color. Oil from this field receives a premium of 40 to 50 cents a barrel because of the high gravity with no trace of water and very little B. S. The average initial production of the wells is about 75 barrels.

The Blankenship Pool, which is an extension of the Sallyards field, is located in the eastern part of T. 26 S.., R. 8 E. About 50 producing wells have been completed, one of which was drilled in with an initial capacity of 1,500 barrels. The sand is reached at a depth varying from 2,334 to 2,530 feet, and in some cases it has been penetrated more than 100 feet.

The other smaller pools in the county, while frequently containing a few wells with good production, are not of sufficient importance as compared with those already described, to be discussed in detail.

The new oil activity in Butler county is centered around the Fox-Bush field and the Blankenship pool. The older fields are inactive as far as further extensions are concerned and only what is termed "inside drilling" is being done. Both the Fox-Bush and Blankenship pools have been greatly expanded during the past year, and it is probable that both these fields will be further extended, the Fox-Bush to the northeast and south and the Blankenship on the southwest and west. The probable area of new production in the future is the southern and eastern parts of the county. At present Butler county is producing as much oil as all the other counties of the state combined.

Rudolph Uhrlaub.

REVIEWS AND RECENT PUBLICATIONS

Field Methods in Petroleum Geology. By Cox, Dake, and Muilenburg. Pocket size, 305 pages, illus. Price $4.00. McGraw-Hill Book Co., New York, 1921.

This manual is concerned with the "new and specialized methods" and with the "adaption of old methods to the new needs" in oil geology and it "makes no attempt to give a popular presentation of field procedure." It is therefore a purely technical discussion of field methods which have not been adequately treated in any of the petroleum handbooks or field geology handbooks heretofore published. A manual of this nature should therefore appeal to the 2,000 or more Americans who are engaged in petroleum geology in this country and abroad, as well as to the hundreds of students who are studying this subject—but this manual fails in its mission.

Structural conditions favorable for oil accumulation are briefly described in the introduction. Chapter I attempts to describe instruments commonly used and Chapter II describes the methods of using them. Chapter III deals with identification of structure in the field and Chapter IV with field operations. The text of 200 pages is followed by a glossary of terms 30 pages in length which have been taken from indices of geological and engineering text books and which have limited relation to the text. An appendix of 65 pages consists of tables.

The possibilities of a manual of this kind are very great but the presentation in this volume is disappointing. The best advice given in the entire work is the key to success in detailed planetable work; namely, "walk the beds." The text describing field work is good, but the end of the book is reached abruptly at the point where the discussion becomes interesting. Several chapters could profitably be devoted to describing methods of work under different climatic and geologic conditions, of which very important phases of geologic work nothing is said.

A lack of co-ordination of the parts of this work is explained by the fact that each author wrote one part. Examples of this defect are: the "open sight alidade" is not described by name under instruments (p. 44), but is referred to later (p. 183) and is defined in the glossary; the barograph, which is essential to accurate aneroid work is likewise not mentioned under instruments or instrument methods. The author of chapters I and II seems to be unfamiliar with the most excellent treatise on "The manipulation of the telescopic alidale in geologic mapping" by K. F. Mather, 1919. He seems to have relied on trade catalogues and engineering works for information and he copies very elementary descriptions of instruments as well as historical notes concerning their invention instead of adequately explaining their use. The stadia hand level, monocular field glass, quarter hair and parallel ruler for ali-

dades, and the sketching board are not mentioned. In fact, the geologist requires many instruments for field and office work besides those listed.

Chapter IV lacks illustrations of contour maps showing the minor structures for which the geologist in the Mid-Continent field now searches between the producing anticlines. Maps are the means by which the geologist presents the results of his investigations. Yet no adequate discussion of maps either purely geologic or structural without areal geology is given. Reports accompany maps when maps are so made as to be self explanatory—the ideal way—and no mention of reports has found a place in this book. Finally at the end of the book (p. 293) the unit of land measurement in Texas, the vara, is omitted.

Minor criticisms may be added. Fig. 5 illustrates an unconformity described as a lensing of sand. Fig. 15 shows gas accumulation under brea where gas could not be expected. It is stated on page 10 that the location of an oil pool under an unconformity can "seldom be foretold" and that buried anticlines may be "absolutely inaccessible to surface study." The writers are referred to the many well known superimposed anticlines of Texas and Southern Oklahoma. Structure contour maps may even be made by projection through an unconformity. The description of a Brunton compass fails to describe how to set off declination. Nowhere is there a suitable explanation of how to read a strike and dip. The description of aneroids is elaborate, yet inadequate. Plate 7 illustrates a stadia rod with the numbers in normal manner instead of reversed. The description of instrument methods lacks illustrations and the Stebinger screw is described but no methods are given for determining its accuracy or for making tables for use with screws whose threads have become worn. No description of primary or secondary traverses is given, nor of the relative degree of accuracy required in the determination of turning points and of side shots.

SIDNEY POWERS

BUREAU OF MINES REPORTS ON OKLAHOMA OIL FIELDS

The U. S. Bureau of Mines has published three reports through local Chambers of Commerce and these reports are not listed among the publications of the Bureau. "Petroleum Engineering in the Hewitt Oil Field, Oklahoma," by T. E. Swigart and F. X. Schwarzenbek, published by and purchasable from the Ardmore Chamber of Commerce, price $1.00, appeared in May, 1921. "Underground Problems in the Comanche Oil & Gas Field, Stephens Co., Oklahoma," by T. E. Swigart, was published in mimeographed form by the Bartlesville Chamber of Commerce, in 1919, and is procurable from them free.

"Report on the Underground Conditions in the Walter Oil & Gas Field," by T. E. Swigart was published in mimeograph form together with six large blue printed sections and one blueprinted structure con-

tour map, by the Bartlesville Chamber of Commerce, in 1920, and may be purchased from them, price $1.50.

It is to be regretted that these excellent publications cannot be printed in regular form in Washington so that they would be readily available to all and that they are not mentioned in the monthly lists of publications of the Bureau.

W. E. Hubbard contributed a brief description of "Regional Geology of the Western Carter County District, Oklahoma" for the Hewitt report. Mr. Hubbard describes an outcrop, south of the Arbuckle Mountains and near the town of Woodford, as "'Red Pennsylvanian" although this outcrop is generally believed to be basal Permian. He refers the producing sands of the Hewitt field to an Upper Pennsylvanian formation which has not been proved to outcrop south of the Arbuckle Mountains. S. P.

BURKBURNETT MAPS

The Bureau of Mines has published four structure contour maps of the Burkburnett district, Texas, and these maps may be obtained from Huey and Philp Hardware Company, Dallas, Texas. The set costs $1.00. Individual maps cost as follows: Old Burk, $ .50, Northwest Extension, $ .25 Texhoma, $ .20, Townsite, $ .15.

ELDORADO, ARKANSAS, MAPS

The Bureau of Mines has also published through the Conservation Commissioner of Arkansas a structure contour map and four cross sections, of the Eldorado, Arkansas, field which may be obtained for $ .65 each from Mr. E. E. Winger, Chief Oil & Gas Inspector, Armstrong Bldg., Eldorado, Arkansas.

AT HOME AND ABROAD

On Saturday, the 23rd of April, 1921, a meeting was held in Delft by the Geological and Mining Society of the Netherlands and its Colonies (Geologisch-Mijnbourvkundig Genootschap voor Nederland en Kolonien). One of the members, Dr. W. C. Klein, gave a lecture on "The Investigations in Caverns of the Island of Java," in which he pointed out the difficulties of this kind of work and proved that subterranean river courses were to be regarded as the origin of these interesting caves. Two members of the Council were elected to take the places made vacant by the resignations of Prof. Urchmann, President, and Dr. Erb, Treasurer. The new officers are Prof. Brouwer as president and Dr. Klein as treasurer.

In the afternoon a lively discussion was held on the application of the theories of Wegener regarding the origin of the islands of the Dutch East Indies, the introduction of which was given by Mr. Wing Easton.

At a meeting of the Institute of Petroleum Technologists on Wednesday, the 27th of April, at the Royal Society of Arts in London, a paper was read by Dr. T. O. Bosworth entitled, "The Mackenzie Oil Field of Northern Canada."

The petroleum geologists of Oklahoma City met at a luncheon on March 26, for the purpose of organizing a local geological society, which has been named the "Oklahoma City Geological Society." The first meeting was held April 1st, at the home of W. C. Kite, and the following officers were elected: President, Irving Perrine; Vice President. L. E. Trout; Secretary-Treas., Harve Loomis; Council: D. W. Ohern, C. T. Griswold, C. N. Gould, W. C. Kite.

Three meetings have been held since that time, and the following subjects were discussed: The Wilcox Sand, by Fritz Aurin and Glenn Clark, of the Marland Refining Company of Ponca City; The Relation of the "Red beds" of southern Oklahoma to production, by George E. Burton; Amarillo Oil and Gas Field, by Dr. C. N. Gould; Granite in Oklahoma Wells, discussion led by Dr. D. W. Ohern.

On May 21, the members of the society held a banquet in honor of their wives. This was the last meeting of the year, the members voting to hold no meetings during the summer months. Regular meetings will be held in the fall, on the first and third Fridays of each month, beginning in September.

Mr. Max W. Ball has resigned as general manager of the Matador Petroleum Company at Cheyenne, Wyoming, to become president of the Ute Petroleum Company and the Western Pipe Line Company at 1104 First National Bank Building, Denver, Colorado.

Mr.. Thomas L. Harrison, Consulting Geologist, announces the opening

of offices at 1106 First National Bank Building, Denver, Colorado. Mr. Harrison was formerly chief geologist for the Midwest Refining Company and member of the firm of Harrison and Eaton.

MR. THEODORE A. LINK, Geologist, Imperial Oil Limited, has left Edmonton for his third season's work in the Fort Norman, MacKenzie River District, Canada. The trip will be made by aeroplane and four more wells will be located.

MR. J. V. HOWELL located the Gypsy Oil Co., gusher in sec. 24, T. 7 N., R. 9 W., Stephens Co., Okla., which is on a higher structure than the original Parsons and Gant well in sec. 25. The subsurface structures are much smaller and more complicated than the surface structures in this area and a syncline seems to have been found between these two wells. Mr. Howell has resigned from the Gypsy Oil Co.

MR. WILLARD MILLER mapped the structure on which the Empire Gas & Fuel Co. completed a well in sec. 6, T. 5 S, R. 1 W., several miles southeast of the Hewitt field.

MR. E. W. MCCRARY located the Wiggam-McAlester pool in T. 32 S., R. 10 E., Chautauqua Co., Kansas.

MR. H. K. SHEARER, formerly chief geologist for the Louisiana Oil Refining Corporation at Shreveport, Louisiana, has returned from Mexico where he has spent ten months in geological work. After visiting the Tampico fields, Mr. Shearer did some reconnaissance in the state of Tabasco for E. B. Hopkins, consulting geologist, 25 Broadway, New York City.

MR. GEO. C. MATSON resigned from the Gypsy Oil Company June 1st and is taking a vacation in the West.

PROFESSOR RAYMOND C. MOORE is taking a vacation.

MR. GEO. E. BURTON is now with the Roxana Petroleum Corp., with headquarters at St. Louis.

MR. C. W. WASHBURNE has been in South America on an extended trip

MR. F. P. GEYER has been elected a member of the board of directors of the Marland Refining Company.

DR. M. I. GOLDMAN has returned to Washington after studying the cap rock of salt domes.

MR. W. R. BERGER has joined the geological department of the Marland Refining Company.

MR. SAM W. WELLS is associated with Mr. Arthur Eaton in New York City.

Mr. Mowry Bates has been in Washington to assist in securing a tax on Mexican oil.

Mr. J. L. Rich has resigned from the Gypsy Oil Company and has opened an office as consulting geologist, 714 Ideal Bldg., Denver, Colo.

The Roark family leads in the number of geologists. Five have studied geology at Oklahoma University and four have been engaged in field work.

Mr. William Kennedy mapped the Lone Star Gas Company structure Section 5, T. 2 S., R. 6 W., Stephens County, Oklahoma.

Mr. Ben C. Belt is credited with the Toteco well in Mexico. He has returned to the United States.

Mr. Angus McLeod will be connected with the Roxana Pet. Corp., in the Gulf Coast Region.

Mr. F. G. Clapp has moved his office to 30 Church St., New York City.

Mr. D. C. Barton located the West-Schenck well at Blue Ridge, Texas, completed by the Amerada Petroleum Corporation in June. This was the fiftieth oil well of the Amerada. Two dry holes and one gas well complete the record for the past year.

Mr. J. W. Bostick is devoting his time to the Kansas & Gulf Oil Company.

Utah and Montana are the popular resorts for geologists this summer.

Mr. V. H. Hughes has moved his office to 406 Exchange Nat'l. Bank Bldg., Tulsa.

Mr. L. J. Zoller has resigned from the National Exploration Company and opened an office at 406 Exchange National Bank Bldg., Tulsa.

Mr. E. B. Hopkins has moved his office to 25 Broadway, New York City.

Mr. Robert Anderson has resigned as Chief Geologist for the Whitehall Corporation, London, and has returned to California.

Mr. L. B. Snider located the Skinner sand well in Section 25, T. 20 N., R. 7 E., Pawnee County, Oklahoma, southwest of Terlton. Mr. Snider has an interest in this well.

Mr. W. Z. Miller located the structure in Section 29, T. 27 N. R. 5 E., Kay County, Oklahoma, on which the Gypsy Oil Company have completed a well.

Mr. R. J. Riggs is Chief Geologist for McCaskey & Wentz with headquarters at Ponca City, Oklahoma. He located the structure on which the

Gladys-Belle Oil Company completed a well in Section 32, T. 21 S., R. 12 E., Lyon County, Kansas.

MR. C. MAX BAUER has been in Wyoming.

MR. E. W. SHAW has established headquarters at 170 Broadway, New York City, and at 302 Cosden Bldg., Tulsa.

MR. E. W. SCUDDER who has been in charge of work for the Arkansas Natural Gas Company in Tulsa has been transferred to Winfield, Kansas, and Mr. S. K. Clark placed in charge of the Oklahoma work with headquarters at Okmulgee.

MR. C. R. ECKES has been in this country to secure geologists and drillers for Venezuela.

MR. J. H. GARDNER claims to have located the discovery well in the Boynton, Oklahoma, field for the Merritt Oil & Gas Co.

MR. JOHN K. KNOX is in India with the Whitehall Petroleum Corporation of London.

MR. L. W. KESLER is representing the Pierce Oil Corporation in Kansas with headquarters at Winfield.

MR. D. M. LOGAN is doing consulting work at Okmulgee, Okla.

MR. CHESTER C. CLARK is with the Roxana Petroleum Corporation at Shreveport, La.

MR. A. C. SPOONER is in South America.

MR. L. V. FEES has rejoined the Texas Co., at Denver, Colo.

MR. A. W. MCCOY located the Beeler et al well in Sec. 18, T. 32 S., R. 13 E., Chautauqua Co., Kansas. He also rediscovered the Gladys Belle structure in Sec. 32, T. 21 S., R. 12 E., first mapped by R. T. Riggs.

MR. E. G. WOODRUFF, of the New England Oil & Pipe Line Co., Tulsa, has gone to South America.

MR. L. A. SCHALL, JR., Chief Geologist for the Texas Co., has returned from South America and is stationed in New York.

NECROLOGY

WILBUR LADDE MOODY

Born February 1, 1888 at Fair Haven Heights, Conn. Died October 9, 1920 near Fresno, California in an automobile accident while on duty for the Associated Oil Company.

Early in his life he showed a marked tendency toward scientific studies—more especially along lines of geology and paleontology. If he went to the mountains or country he would come home with his pockets and other available receptacles full of stones of various color and shape. A trip to the seashore would mean his pockets full of shells..

At the age of twelve he came to Pasadena, California, with his parents, Mr. and Mrs. Charles A. Moody and his younger brother Graham Blair, and two years later with the family moved to Los Angeles where he lived until the death of his father in 1910. During the spring of 1911 he with the combined efforts of his mother and brother established a home in Berkeley, California which became permanent.

He attended Throop Polytechnic Institute at Pasadena, completing the grammar school work in 1902, and was graduated from the Academy June 7, 1906. He took one year of practical field work—surveying and some underground mining—after which he entered the University of California and was graduated in 1911 with the degree of B. S. in Mining.

In January 1911, with seven other seniors, he was chosen to meet with one faculty man and organize a local society which later became the Epsilon Chapter of Theta Tau. At the spring election of the Alpha Chapter of Tau Beta Pi in 1910 he was elected treasurer. In addition to being a member of Theta Tau and Tau Beta Pi, he belonged to the honor societies Sigma Xi and Mim Paph Mim, and was a member of the National Geographic Society, the American Association for Advancement of Science, the American Institute of Mining and Metallurgical Engineers, and the Paleontological Society.

A short time before his graduation from college he secured a position in the Geological Department of the Southern Pacific Company where he was employed at the time of his death. From 1911 to 1916 Mr. Moody was engaged in geological surveys and investigation of mineral resources in charge of parties in Southern California, the Sierra Nevada Mountains of eastern California and across Nevada along the Southern Pacific railroad lines. About 1917 his work shifted from mineral land surveys to oil land investigation. During 1918, 1919 and 1920 to the time of his death he devoted his time exclusively to oil exploration, investigation and appraisal of developed properties, the last of these being a detailed survey of the Kern Oil Field. In 1919 Mr. Moody was detailed to supervision of the work of Resident Geologist for the Associated Oil Company and in this capacity, while returning from the

Coalinga Oil Field, he lost his life. August 15, 1920 he was married to Miss Edna Howell.

Mr. Moody was recognized by his employer and associates as a man of thorough qualifications as a geologist; competent, reliable and wholly devoted to his duties. He was held in the highest esteem personally by his associates with whom he had been in close touch for ten years.

SAMUEL D. BRIDGE, JR.

Samuel D. Bridge, Jr., was born in 1895 at Monterey, Mexico, and died at Gachala, Colombia, April 8, 1921. His boyhood days were spent in Mexico. Later he attended the St. Paul's School in New Hampshire, and the Terrell Preparatory School in Dallas, Texas. He entered the Sheffield Scientific School in 1913, and finished in 1917, receiving the Degree of Ph. B. in Mining Engineering. A month or so before school was out he joined the First Officers' Training Camp at Leon Springs, Texas, and there received a commission as Lieutenant. He was among the first few chosen to do service in France, and went over with a company of heavy artillery, remaining there until the close of the war. In 1919 he began working for the Texas Company and went with a geological party to Peru, South America. He later returned and worked in the North Texas fields, then joined another party for the same company and went to Colombia. It was there that he contracted the fever from which he died in Gachala on the eighth of April, having been sick only a few days. His body was returned to his home in San Antonio and buried in the Mission Burial Park. He is survived by his parents, Mr. and Mrs. Samuel D. Bridge, Sr., and three sisters, Misses Margaret and Mary Bridge, and Mrs. Charles R. Hickok of New York City, and a brother, James P. Bridge, who is attending Yale University.

THE CONSTITUTION OF
THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

ARTICLE I.—Name

This Association shall be called THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS.

ARTICLE II.—Object

The object of this Association is to promote the science of geology, especially as it relates to petroleum and natural gas; to promote the technology of petroleum and natural gas and improvements in the methods of winning these materials from the earth; to foster the spirit of scientific research amongst its members; to disseminate facts relating to the geology and technology of petroleum and natural gas; to maintain a high standard of professional conduct on the part of its members; and to protect the public from the work of inadequately trained and unscrupulous men posing as petroleum geologists.

ARTICLE III.—Members

Section 1—Any person actively engaged in the work of petroleum geology or in research pertaining to petroleum geology or technology is eligible to active membership in the American Association of Petroleum Geologists, provided he is a graduate of an institution of collegiate standing in which institution he has done his major work in geology, and in addition has had the equivalent of three years' field experience in petroleum geology; and provided further, that in the case of an applicant for membership who has not had the required collegiate or university training, but whose standing in the profession is well recognized, he shall be admitted to membership when his application shall have been favorably and unanimously acted upon by the executive committee; and provided further that these requirements shall not be construed to exclude instructors and professors in recognized institutions of learning whose work is of such character as in the opinion of the executive committee shall qualify them for membership.

Section 2.—Any person having completed as much as twenty hours of geology, (an hour shall here be interpreted as meaning as much as sixteen recitation or lecture periods of one hour each, or the equivalent in laboratory) in a reputable institution of collegiate or university standing, or who has done field work equivalent to this, shall be eligible to associate membership in the American Association of Petroleum Geologists, providing that at the time of his application for membership he shall be engaged in geological studies in an institution of collegiate or university standing, or shall be engaged in geological work.

Section 3.—Active and associate members shall be elected to the Association according to the qualifications outlined in sections 1 and 2, provided that the applicant properly fills out the regular application blank,

including the signatures of THREE active members of the Association, and that such application be approved by at least three of the members of the executive committee of the Association as provided for in Article IV, Sections 1 and 4.

Section 4.—Associate members shall enjoy all privileges of membership in the Association, save that they shall not hold office, sign applications for membership, nor vote in business meetings; neither shall they have the privilege of advertising their associate membership in the Association in professional cards, nor shall they have the privilege of signing professional reports as associate members of the Association.

Section 5.—Each aplicant for membership shall formally be notified in writing by the secretary of his election, and shall be furnished with a membership card for the current year; and until such formal notice and card are received, he shall in no way be considered a member of the Association.

Section 6.—Applications for membership may be accepted at any time, but unless an applicant shall have his application approved and have been formally notified by the secretary of his election at least one month before the annual meeting, he shall not be allowed to participate in the business of said annual meeting.

ARTICLE IV.—OFFICERS

Section 1.—The officers of the Association shall consist of a president, a vice-president, a secretary-treasurer, and an editor-in-chief. These together with the retiring president shall constitute the executive committee of the Association.

Section 2.—The officers shall be elected annually from the Association at large.

Section 3.—No man shall hold the office of president or vice-president for more than two years in succession.

Section 4—The executive committee shall consider all nominations for membership and pass on the qualifications of the applicant; shall have the control of the Association's work and property; shall determine the manner of publication and pass on all materials presented for publication; and may call special meetings when and where thought advisable and arrange for the affairs of the same.

Section 5.—The officers elect shall assume the duties of their respective office one month after date of election.

ARTICLE V.—MEETINGS

The annual meetings shall be held at a time most convenient for the majority of the members at a place designated by the executive committee. At this meeting the election of members shall be announced, the proceedings of the preceding meeting be read, all society business transacted, scientific papers read and discussed, and officers for the ensuing year shall be elected.

ARTICLE VI.—AMENDMENTS

This constitution may be amended at any time providing that such amendment is proposed and signed by at least five members of the Association, and is presented and discussed at any annual meeting of the Association. The secretary shall take a ballot of the membership by mail within thirty days after the meeting of the Association, and a majority vote of the ballots received shall be sufficient to amend, providing three-fourths of the members return ballots.

ARTICLE VII.—PUBLICATION

The proceedings of the Annual Meeting and the papers read shall be published in an annual bulletin. This shall be under the immediate supervision of the Editor-in-Chief, assisted by a Publication Committee, consisting of three members to be appointed by the President.

ARTICLE VIII.—SECTIONS

Section 1.—Regional sections of the Association may be established provided the members of such sections shall perfect a regional organization and make application to the executive committee, who shall submit the application to a vote at a regular annual meeting; a vote of two-thirds of the members present being necessary for the establishment of such a section, and provided that the Association may revoke the charter of any section by a vote of two-thirds of the membership.

BY-LAWS

Section 1.—Dues. The regular dues of an active member of the Association shall be ten dollars. The yearly dues of an associate member of the Association shall be six dollars. The annual dues are to be paid to the secretary-treasurer on or about January first for the year ending the following December.

Section 2.—Any member who shall fail to pay his regular annual dues for a period of one year may be suspended by a vote of the executive committee, but may be reinstated upon the unanimous consent of the committee.

Section 3.—The payment of the yearly dues entitles the member to receive without further charge, one copy of the proceedings of the Association for that year.

Section 4.—Any member who shall be guilty of flagrant violation of the established principles of professional ethics may upon the unanimous vote of the executive committee be suspended from membership, provided that such person shall before suspension be granted a hearing before the entire executive committee.

AMENDMENTS

These By-Laws may be amended by the vote of three-fourths of the active members present at any annual meeting.

Errata in Volume 5, Number 2 of the Bulletin

P.216 The first line below the cut, "ner's Creek, a small tributary of the Brazos river, cuts across the" should be dropped to the bottom of the page.

P.218 Third paragraph, second line, for "9500", read "4500".

P.220 Fig.3 On the left scale, for "feet", read "inches".

P.225 First paragraph 22d to 24th lines, should read "The mound represents a deformation of the plain here which is of Pleistocene and probably late Pleistocene or recent age. The base of the Lafayette, etc."

P.229 First line, for "less", read "lesser".

P.231 Third paragraph in place of "Big Oil Co.," read "Big Belt Oil Co."

P.231 Fourth paragraph in place of "Big Belt Oil Company" read "The Texas Company".

P.240 Fig. 11 relates only to the T. T. Co's Abrams 1.

P.242 Table 1, the localities after and including Port Arthur-Jefferson Co. are in Texas and not in Mississippi.

P.244 First line last paragraph, in place of "oil field" read "old field."

P.248 Fifth line in place of "4 wells", read "24 wells".

P.297 First line should be first line on P. 295.

P.328 The first line on this page is omitted. Read "*James H. Gardner*—I think we should not overlook the matter of local metamorphism because."